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SATSIN SYSTEM MANUAL

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13. ABSTRACT *(Maximum 200 words)*

This report outlines the design, functions and operation of the HAARP Diagnostic Satellite Scintillation (SATSIN) system that will be used to characterize the structure and dynamics of F region ionospheric irregularities created during HF heating. When in routine operation, the SATSIN system will be located so that the propagation path from satellite radio beacons passes through the heated volume created by HAARP. The signal, altered in phase and amplitude by the irregularities, is received by the SATSIN array of eight antennas and is processed to extract the spatial and temporal characteristics of the scintillation. From this information, the strength, shape and motion of the in situ irregularities generated by HAARP can be implied. The hardware and software components of the system are reviewed, and the installation and operation in conjunction with the HAARP network are outlined.

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1. INTRODUCTION

The HAARP Diagnostic Satellite Scintillation (SATSIN) system will be used to characterize the structure and dynamics of F region ionospheric irregularities created during HF heating. Those irregularities are produced by a thermal self-focusing instability at the altitude where the heating signal frequency matches the plasma frequency of the electron density profile. The cross-magnetic field dimension of these irregularities depends upon many factors, but it is typically a few hundred meters. At these scale sizes, the perturbations in electron density cased by the instability can cause weak to moderate transionospheric phase and amplitude scintillation at VHF and UHF frequencies.

When in routine operation, the SATSIN system will be located so that the propagation path from satellite radio beacons passes through the heated volume created by HAARP. The signal, altered in phase and amplitude by the irregularities, is received by the SATSIN array of eight antennas and is processed to extract the spatial and temporal characteristics of the scintillation. From this information, the strength, shape and motion of the *in situ* irregularities generated by HAARP can be implied.

This report outlines the design, functions and operation of the SATSIN system. Section 2 briefly describes the hardware components that are used, and Section 3 summarizes the hardware/software functions of data collection and processing. Section 4 outlines the field installation and operation of SATSIN. Hardware component details are specified in the Appendix.

2. HARDWARE SUMMARY

In terms of hardware, the SATSIN system consists of a high-performance eight-channel antenna/receiver system, two networked computers, and associated peripheral electronics. A block diagram of the routine operational configuration of the system is illustrated in Figure 1. The dashed boxes in the figure indicate GFE equipment that is currently not installed as part of the system.

One computer in the SATSIN system (Data Acquisition/Transmission, or DAT) manages the receiver, optimizing signal levels and tuning, performing periodic diagnostic tests, and collecting raw signal data. The DAT also digitizes and numerically detects the raw signals, and transmits the data to the second computer (Display/Integration/Statistics, or DIS) over an ethernet connection. The DIS performs the major numerical tasks: the spectral processing and correlation analysis of the spaced antenna data, and the conversion of output parameters into netCDF format. Its user interface can be used to display input and output data in real time, including the input data time series and the computed temporal and spatial statistics. The DIS also provides the system's generalized ethernet access to the HAARP Diagnostics Control Center (HDCC), and Internet telescience users.

Brief hardware descriptions of the various components in the system are described in the following paragraphs.

2.1 Receiver

The SATSIN receiver is an eight-channel superhetrodyne unit custom built by NoiseComm, Inc. (NCI) to SRI requirements (*Specification for the Sat Sin Receiver*, 1992). Details about the receiver circuitry and its synthesizer modules are described in a manual prepared by the manufacturer (*SAT SIN Receiver NCI 4116 Operating Manual*, 1992). The primary RF electrical performance features of the receiver are listed in the Appendix.

The receiver tunes between 240 MHz and 245 MHz with a resolution of 1 Hz. Received signals pass through a preselector and are down converted to intermediate frequency (IF) stage at 21.4 MHz. The signal is further translated to a low video output centered at 50 Hz. It is a narrow-band receiver throughout to maximize sensitivity, with the bandwidth eventually limited to 100 Hz by the output stage. An electrical block diagram of the receiver is shown in Figure A.1.

Since any difference between receiver stages can compromise the analysis of spaced-receiver data, the NCI receiver was designed specifically to minimize the phase differences between the eight receiver channels. This was accomplished by careful design and by use of synthesized local oscillators with excellent stability and jitter characteristics. The result is that the phase drift and jitter are always less than 5° rms.

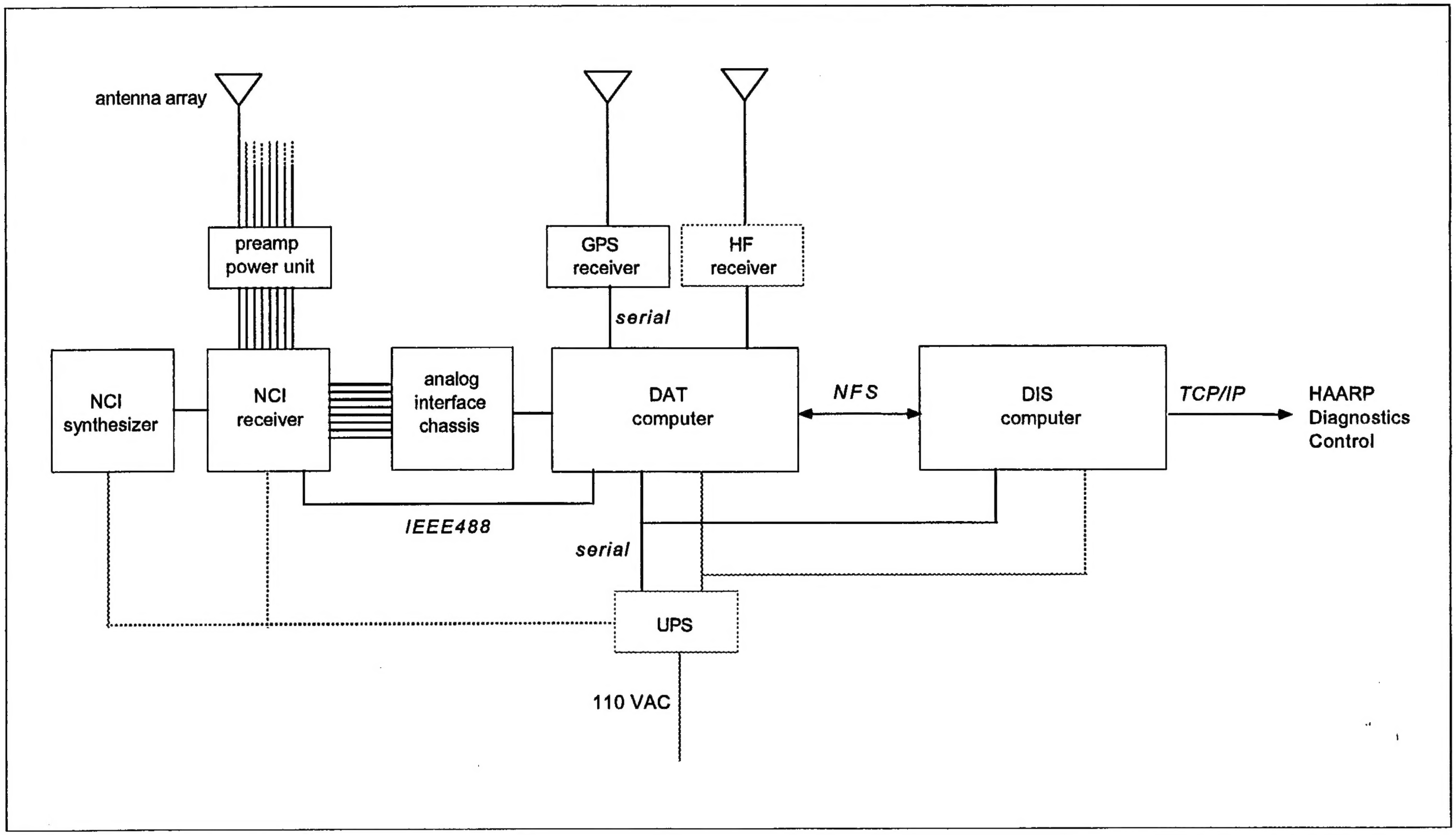

Figure 1. SATSIN routine operation hardware configuration

This assures that instrumental effects on the correlation analysis will not be significant, and also allows the receiver to be used in other non-routine modes, such as interferometry.

All of the NCI receiver functions are controlled using IEEE-488 commands from the DAT computer. This includes frequency tuning, IF gain control level, and built-in test (BIT) functions. The gain and frequency of all channels within the receiver are the same. The BIT uses a noise source built into the receiver that is coupled into the RF front end of all eight receivers through an step attenuator. This provides the capability of making precise calibrations under computer control, which will be done periodically during routine operation. Furthermore, a pre-programmed test sequence built into the BIT can be initiated that confirms uniformity between channel gain at a series of IF attenuation levels and reports discrepancies to the controlling computer. This same sequence is also exercised whenever the receiver is powered up.

The routine operational function of the receiver is described in Section 3.1. Additional hardware details about the receiver are included in the Appendix.

2.2 Antenna Array and Preamplifiers

SATSIN uses eight identical vertically mounted helix antennas with the configuration shown in Figure 2. Per specifications (*Specification for the SATSIN Antenna System,* 1992), these have a beamwidth of approximately 55°, corresponding to a boresite gain of about 12 dBi. The receiving element is matched to 50Ω using a $1/4\lambda$ transformer at the base of the center post. This avoids the need for critical placement of the electrical element relative to the ground plane, and thus, simplifies field assembly.

The helix attaches to the ground plane reflector by way of a sealed housing that contains one or two preamplifier modules and a bandpass filter. The bandpass filter assumes that any strong interfering signals do not compromise the performance of the preamplifiers. The antennas will be placed as much as 1000 feet from the receiver and connected to the receiving system using 9913-type low-loss RG-8 cable. The preamplifiers each have a gain of 20 dB, and are used to offset the loss of signal in the cable. By using either one or two preamplifiers and attenuators within the electronic housing, the signal level to the receiver can be adjusted for any particular antenna installation. The preamplifiers are powered through a bias tee by 15 VDC that is applied to the center conductor of the RF cable. On the receiving equipment end, that power is supplied through another series of bias tees in the Preamp Power Chassis (see Figure 1).

Although the antennas will be permanently installed at HAARP, preliminary fielding of the SATSIN system required that they be easily disassembled and portable. Assembly details are described in Section 4, Field Operations. Mechanical and electrical drawings and information about the antennas and preamplifier assemblies are provided in the Appendix.

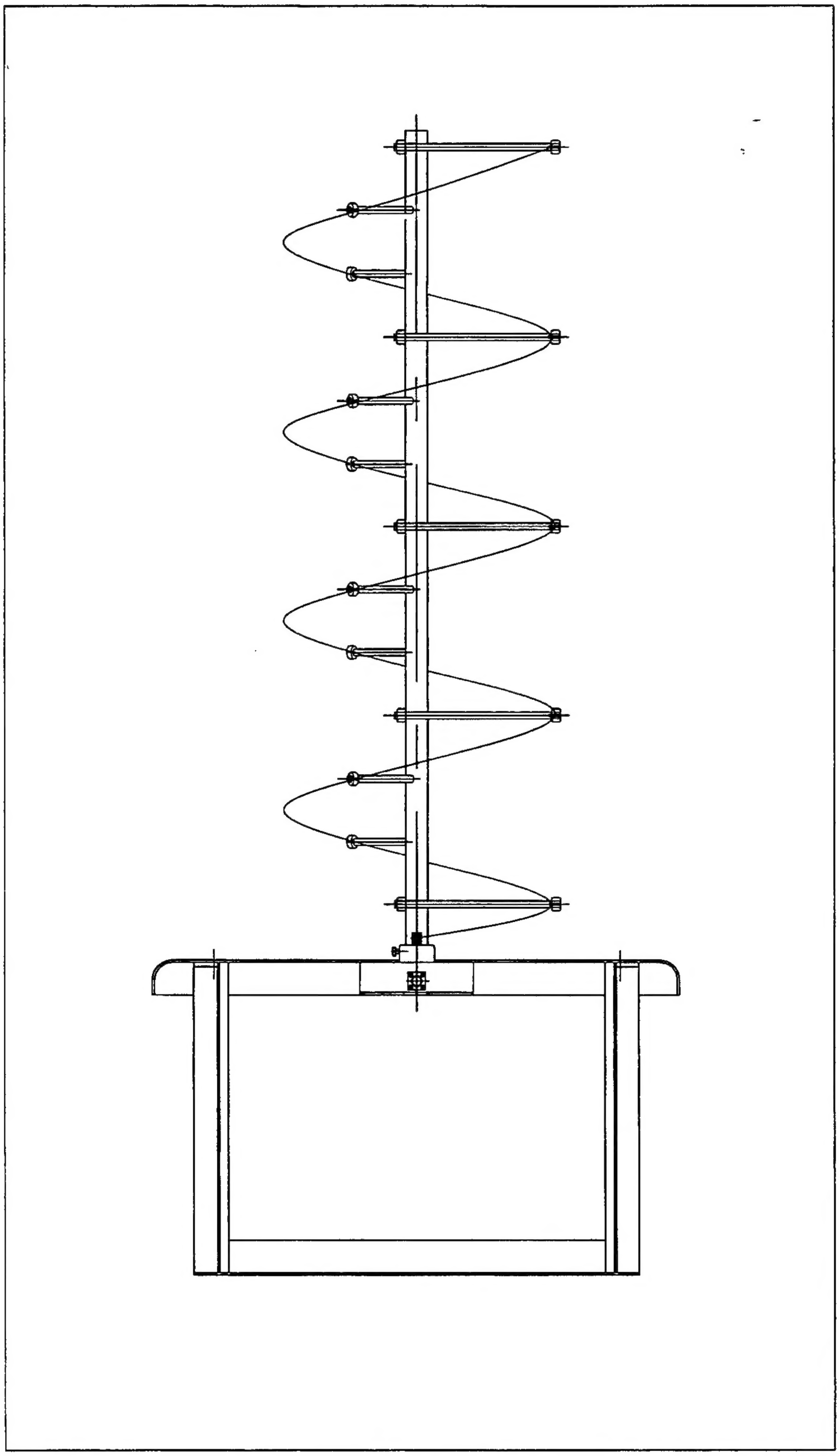

Figure 2. SATSIN UHF helix antenna with stand

2.3 Data Acquisition/Transmission Computer (DAT)

The DAT chassis contains a passive-backplane, ISA-bus 50 MHz 486 CPU and a series of interface cards. The passive backplane design was chosen because it ruggedized, and because it can be serviced or replaced rapidly in the field. An ethernet card (Excelan E205T) provides the communication capability with the DIS, and a National GPIB-AT card provides IEEE-488 control of the receiver functions. The computer has a moderate-size IDE hard disc for system use and local data storage, and a conventional VGA display. Details about the interface hard settings and drivers for the various interface cards in the DAT are included in the Appendix.

In terms of system function, the most complex card in the DAT is the analog-to-digital converter (ADC), which is a Data Translation DT2838. As indicated in Figure 1, the eight low IF signals from the NCI receiver are cabled into the Analog Interface Chassis using matched-length BNC cables. This chassis houses a Data Translation interconnect board that attaches via a high density cable to the ADC card in the DAT. The sampling resolution of 16 bits is four more bits than is typically used, and assures that there is no loss of dynamic range in the data system relative to that of the receiver.

A table in the Appendix lists the settings for the interface cards in the DAT.

2.4 Display/Integration/Statistics Computer (DIS)

In accordance with the common hardware requirements set out for all HAARP diagnostics, the second computer in the SATSIN system (the DIS) is a UNIX workstation. In particular, it is a Sun Sparc5 computer running Solaris (the Sun version of UNIX System V). Its hardware configuration is simple, consisting of an internal 1 Gbyte disc, a SCSI interface for external data archive devices, and an ethernet interface for communication with both the DAT and the remote HAARP Diagnostic Center.

A brief summary of the Sparc5 specifications are included in the Appendix.

2.5 Network Hardware

When installed as a HAARP diagnostic, SATSIN system will be fielded a number of miles from the HAARP Diagnostic Control Center (HDCC) but must maintain real-time data communication with the HDCC computers. An optimum means to do this is over an ethernet connection because of the well-established, platform-independent protocols that have been developed for TCP/IP. A practical means to supply ethernet communication a remotely sited system is through a serial router. As is illustrated in Figure 3, this device attaches through a repeater to the ethernet ports of the DIS and DAT

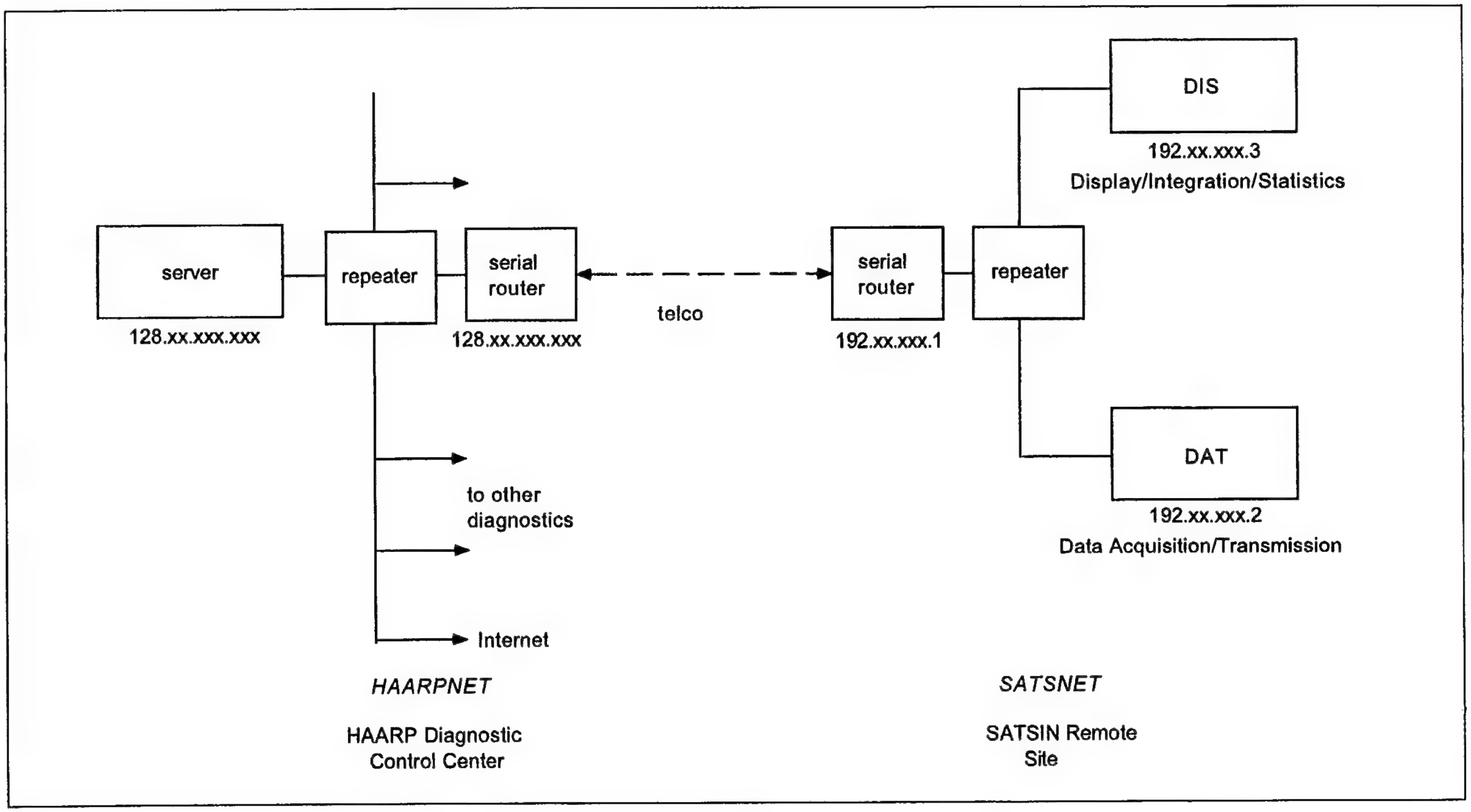

Figure 3. Network configuration between the remote SATSIN site and the HAARP Diagnostics Control Center

computers, and autodials a similar device at the HDCC over a telephone line. Once connected, the serial routers supply all TCP/IP functionality between the client computers (the DAT and DIS) and the HDCC server computer. Data speeds of approximately 30 Kbaud can be achieved over good quality telephone lines, which is well above that required for SATSIN system control and data transfer.

The serial routers will be supplied GFE; their specifications, along with those of the repeater are given in the Appendix.

2.6 GPS Clock

The SATSIN system assures that data are properly and accurately time-tagged by periodically resetting the DAT and DIS system clocks to that of the GPS system. This is done using a Trimble Accutime Smart Antenna. It consists of an antenna and 6-satellite receiver in a small housing that is mounted outside the SATSIN site. The receiver is powered from a dedicated supply in the SATSIN electronic enclosures. Data is continuously output by the receiver and is input to the DAT computer through one of the computer's RS232 ports.

The interconnection diagram for the GS receiver is included in the Appendix.

2.7 HF Receiver

In order to properly correlate changes in the characteristics of the transionospheric satellite signal with those of the heating carrier, SATSIN monitors the HAARP portion of the HF spectrum using relatively rapid scans. In this way, changes in the heating frequency (although not its modulation, if any) can be determined with good time resolution. Some relative idea of transmitted signal strength can also be estimated although there is ambiguity in this measurement under some propagation conditions. The antenna used for the HF system is an active dipole which is compact but still provides good response down to approximately 2 MHz.

The HF receiver will be supplied GFE at some future date, so the details of its computer control cannot be specified. The frequency, gain and bandwidth of the receiver will be controlled, and an estimate of the measured signal strength will be returned by the receiver. The protocol used by the DAT to communicate with the HF receiver will be either RS232 or IEEE488.

2.8. Power Conditioning

To assure consistent operation of the SATSIN system, the two computers and receiver are powered through an Uninterruptable Power Supply (UPS). Its use is

particularly critical for the DIS computer because of the vulnerability of UNIX to power outages. In function, the DIS computer senses the loss of power through a serial interface on the UPS, and notifies the DAT which then completes its current task and goes through a graceful shutdown. The DAT then continues to monitor the battery state of the UPS and eventually shuts the unit down if low capacity is sensed.

Additional information about the requirements for the UPS, which will be supplied GFE, and its electrical interface are included in the Appendix.

3. SYSTEM FUNCTIONAL DESCRIPTION

3.1 RF System

3.1.1 Manual and Computer Control

The NCI 4116 receiver is designed to operate primarily under computer control, and thus has a minimum of front panel controls. As the illustration of the receiver's front panel (Figure A.2) shows, there are thumbwheels that can be used to set its frequency and IF gain, a MODE selection switch, and a RESET button. The RESET forces the receiver to clear any previous commands, and to run a self test sequence. The multiposition MODE selector switch has four positions: TEST, MANUAL, AUTO and REMOTE. These are four of the receivers operational modes. Some of the modes can be set only from the front panel, others only by communication from the computer, and some by either method. The various modes and their functions are as follows:

> TEST Mode (front panel switch only): In this mode, the receiver will accept commands only from the front panel and internal options switches, and the IEEE488 command interface is disabled. When the mode selector switch is on TEST, the receiver initiates a test sequence and reports status on the front panel display window. There are a series of test sequences stored in EPROM; the selection of any particular test can be made by the internal control dipswitch on the back of the receiver (see Figure A.4 in the Appendix). In the TEST mode, the test sequence is repeated whenever the front panel frequency or gain thumbwheels are changed. When initiated, any test sequence takes approximately 30 seconds to complete.
>
> MANUAL Mode (front panel switch only): In MANUAL mode, the receiver will also accept commands only from the front panel and internal option switches, and the IEEE488 command interface is disabled. Upon power up, or when the RESET is activated, the self test selected by the internal option switches is run and the results displayed on the front panel.
>
> AUTO Mode (front panel switch or IEEE488 command): In this mode, the receiver will respond to the latest command, whether it comes from the computer,

or from a change in the thumbwheel switches. Upon power up, or when the RESET is activated, the self test selected by the internal option switches is run. The results of the test are displayed on the front panel and reported over the IEEE488 line to the computer.

REMOTE Mode (front panel switch or IEEE488 command): This is the routine operating mode of the receiver in which it responds only to IEEE488 commands, changes in the MODE switch, and the RESET button. It will not respond to changes in the thumbwheel settings, although the initial frequency and gain are those read from the thumbwheels on power up. Upon power up, or when the RESET is activated, the self test selected by the internal option switches is run. The results of the test are displayed on the front panel and reported over the IEEE488 line to the computer.

REMOTE TEST Mode (IEEE488 command): There is little use for this mode which activates the TEST relay, since all of the same functions can be accessed in AUTO or REMOTE modes.

REMOTE LOCKED Mode (IEEE488 command): Also of little use, this mode disables all front panel controls and the RESET button.

REMOTE LOCKED TEST Mode (IEEE488 command): Similarly of little use, this mode disables all front panel controls and the RESET button, but activates the TEST relay whenever the receiver is in AUTO or REMOTE mode.

The function and purpose of each of the test programs installed on the receiver EPROM is described in the NCI instruction manual (*NCI*, 1992). As was noted above, any of the tests can be selected using the internal options dip switch of the receiver, but can also be selected under computer control. In general, there should be no reason to alter the receiver dip switch setting from its current selection of BIT Test 2. If it is altered, there is a possibility that the BIT noise test program used for routine checks on receiver function and linearity may malfunction and need to be revised.

The command protocol to control the receiver over the IEEE488 line is straightforward, and consists of the ASCII command strings shown in Table 1.

Among the control commands, all are self-explanatory other than the two referring to the BIT noise. Noise Offset and Noise Attenuation are two different ways to set the output level of the built-in noise source and are applicable only when used in conjunction with the prior selection of a Test Sequence. Use of the Noise Attenuation command is not suggested because it appears to malfunction under some conditions. The Noise Offset command is the one used by the routine noise source calibration program (Section 3.1.3)

and relates to the noise power input to the receiver as follows:

$$N = G - O + 34.0$$

where N is the noise level in dBm, G is the receiver gain in dB and O is the noise offset in dB.

The library of software for the NCI receiver that is included with the SATSIN software (*Livingston*, 1995) has a number of high-level functions that use these commands to control the receiver. Any software written to control the receiver using the DAT computer should use these higher level routines.

Table 1. NCI Receiver Control Commands

Commands (*d* is a decimal and *h* is a hexidecimal digit):		
Frequency	F24*dddddd*	Hz
IF Gain	G*ddd*	0 - 123 dB
Noise Offset	O*ddd*	0 - 123 dB
Noise Attenuation	A*ddd*	0 - 123 dB
Test Sequence	T*h*	test number 1-6
Mode	M *d*	1 = TEST
		2 = MANUAL
		3 = AUTO
		4 = REMOTE
		5 = REMOTE TEST
		6 = REMOTE LOCK
		7 = REMOTE LOCK TEST
Query for settings:		
Frequency	F?	Hz
IF Gain	G?	dB
Noise Offset	O?	dB
Noise Attenuation	A?	dB
Test Sequence	T?	test number
Mode	M?	mode number
All of the above	??	

3.1.2 Signal Levels

The NCI receiver has an operating range of approximately 50 dB over which all channels are linear to within better than 0.5 dB. The linearity is illustrated in Figure 4

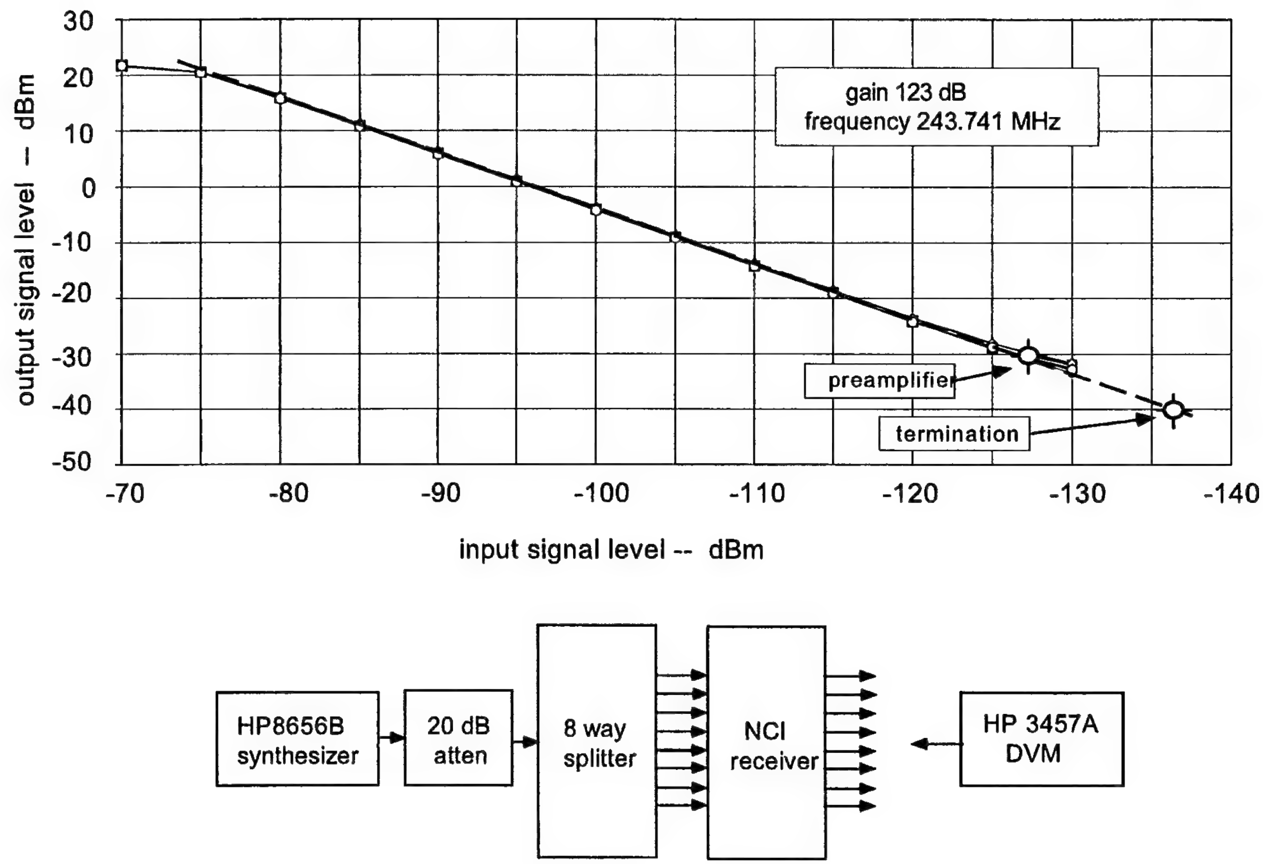

Figure 4. Transfer characteristic of the NCI receiver

which shows the receiver transfer function for all channels, when operated at the maximum IF gain of 123 dB. The test configuration used to make the measurement is as shown. For signal level inputs below -130 dBm, the signal generator could not be used since its noise dominated the measurements. Instead, at the low end of the signal scale, there are two point measurements for all eight channels; one is the receiver output level for a terminated input (near -40 dB output), and the other the noise level with the antenna/preamplifier attached in the absence of a signal.

In operation, it is mandatory that the incoming signal level is well within the linear range of the receiver to obtain accurate statistical characterizations of the scintillation. Under extreme scintillation conditions at high latitudes, the received signal can vary between about +10 and -25 dB from its mean (non-fading) level. Saturation of the IF occurs starts to occur at input signal levels above about -75 dBm, so the maximum non-fading signal level input to the receiver needs to be well below -85 dBm. Ideally then, the non-fading signal level should be approximately -90 dBm maximum, which still allows adequate linear dynamic range for weak or fading signals.

The nominal received signal levels for the SATSIN system operating at the HAARP site in Alaska can be estimated using a link budget computation. The signal input at the receiver terminals is:

$$P_r = P_{teff} - 32.5 - 20 \log R - 20 \log F + G_{ant} + G_{pre} - L_l$$

where:

P_{teff} is the effective radiated power of the satellite, dB
R is the range to the satellite (18,000 km to 40,000 km at HAARP)
F is the operating frequency of 244 Mhz
G_{ant} is the antenna gain, dB
G_{pre} is the preamplifier gain, dB
L_l is the cable loss, preamplifier to receiver (1.95 dB/100 ft at 250 MHz), dB

The effective radiated power for the satellites in use is not specifically known, although estimates from operations of SATSIN at Stanford suggest that it is near 48 dBm at high latitudes. The primary error in this estimate arises from the spacecraft antenna pointing loss which increases significantly as the latitude of the receiving station decreases below about 60°.

Using current orbital elements, the estimated minimum received signal is that from the short baseline (250 foot cable) antennas since they use only a single preamplifier module. That level is estimated to be -100 dBm, which is lower than the optimum, but is an acceptable level. The maximum signal level for the long (1000 ft) cable runs is about -87 dBm, and is well matched to the optimum range. As is noted in Section 5, the final installation at HAARP will start with an optimization of the signal levels for all the baselines of the permanent antenna installation using both preamplifier modules and attenuators mounted in the electronic housing.

It is also useful to determine the minimum detection level of the receiver system when the antenna and preamplifier noise is included. The preamplifier effective noise temperature in degrees is given by:

$$T_{pre} = (N_f - 1) 290$$

where their noise figure, N_f, has been measured to be approximately 0.5 dB, or a noise temperature of about 35 °K. The noise power at the input to the receiver is:

$$P_{noi} = 10 \log [k B (T_{ant} + T_{pre})] + G_{pre} - L_l$$

where:

k is Boltzmann's constant (1.38×10^{-23} watts/Hz/°K)
B is the effective receiver bandwidth, about 2500 Hz
T_{ant} is the sky temperature, about 500° K at 244 MHz

This expression predicts that for a preamplifier gain of 20 dB, the noise power at the receiver input should be approximately -128 dBm for the antenna installation at Stanford which has cable loss of about 10 dB. Considering the approximate nature of the sky temperature estimate, this agrees well with the measured noise level of -127 dBm shown in Figure 4.

Another point of reference is the receiver output level for a terminated 50 ohm input. The receiver, itself, has a noise figure better than 5 dB, corresponding to an effective temperature of 630° K. Its noise power is the therefore about -137 dBm. This also agrees very well with the experimentally measured value, providing confidence in both the bandwidth value and noise figure of the receiver.

3.1.3 RF Built In Noise Source

As has been noted, the NCI receiver has a built-in noise source which is activated on power up, and can be exercised under computer control. The noise source is controlled by an EPROM programmed with a series of test sequences; these tests and their applicability are described in the manufacturer's receiver manual (*NCI*, 1992). It is not possible to activate the noise source under computer control without using one of these EPROM sequences.

The noise source is useful in that it provides a built-in test (BIT) to confirm that all channels are functioning and retain their linear operating range. The receiver output power as a function of noise input level (noise offset) is shown in Figure 5 for a receiver IF gain setting of 123 dB. As the figure shows, the stepped noise source accurately

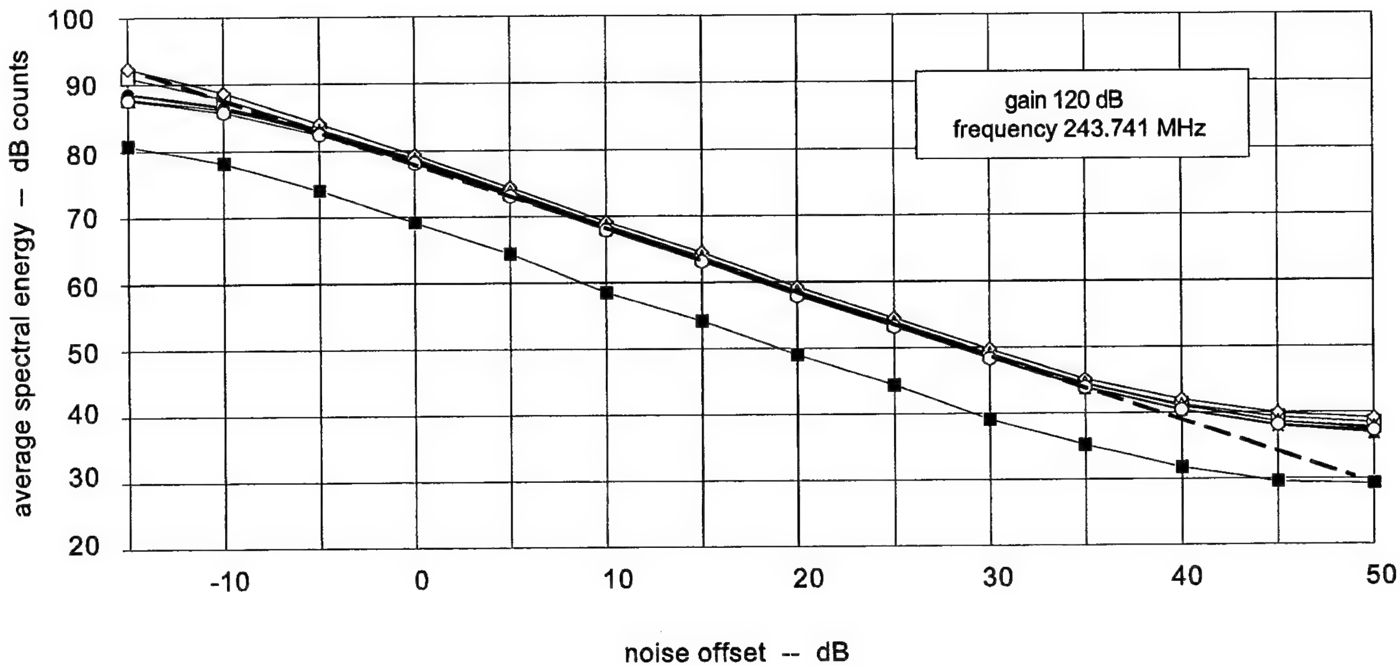

Figure 5. Transfer characteristic of NCI receiver for BIT noise calibration

reproduces the same receiver characteristic as that shown in Figure 4 where an external synthesized signal was used. This makes the BIT useful as a means to verify proper operation of all receiver channels during routine operations.

As has been noted, Test 2 is the most (or only) useful of those programmed into the receiver EPROM. During that test, the noise source is activated and two passes are made through all eight receivers to verify that the signals levels are within preset boundaries. This is the test that is activated at power up, and reports any discrepancies on the front panel display. Test 2 is also the test that is utilized by BITCAL, the operational program used to verify that the receiver gain and linearity are normal. It is called on a periodic basis, and also whenever an individual receiver channel loses its signal. The program sets the receiver gain at 120 dB (close to the nominal operating gain of 123 dB), activates the noise source and steps the noise attenuation over a specified range. The expected response of the receiver is programmed into the code, and any exceptions to that performance are noted. More details about the routine use of the BITCAL program are included in Section 3.2.5.

3.2 DAT Computer Operations

The DAT computer is dedicated to the time-critical functions of data collection, signal monitoring and network communication. These are appropriately handled by its MS DOS operating system. Essential details about the operating system configuration are listed in the Appendix.

3.2.1. Overall Operation

During routine operations, the DAT computer boots into an automatic control mode on power up. More specifically, a command loop called INIT.BAT is entered. This control file consists of a series of calls to programs on the computer, and is listed in Table 2. Actions taken while within that loop depend upon (1) the availability and character of the satellite signal being received, and (2) any control commands supplied by the DIS computer.

The DAT and DIS computers will normally communicate, both in terms of control and data, by way of shared files. Physically, these files are on the DIS computer, and are accessed by the DAT using the Network File System (NFS) TCP/IP utility. The NFS utility makes disc space on the DIS to appear as a DOS disc, in the SATSIN case, on drives F: and G:. Near the beginning of the INIT.BAT is a call that attempts to establish the remote mount of disc F: on the DIS computer (using the NET LINK command). The only situations that would prevent a successful remote mount would be if the network cable was disconnected or that DIS had been shutdown and/or powered down. A check on the existence of a static file (EXIST.TXT) on the remote mount is the actual mechanism used to verify the remote mount has been accomplished.

Table 2. DAT Computer Operations Control File (INIT.BAT)

```
:Start
rem -- Set time from GPS
call c:\satsin\ops\timeset.bat

rem -- Check if power outage exceeded 30 minutes
c:\satsin\offtime.exe
rem -- Short down  time
if errorlevel 1 goto Netlink
rem --  Long down time, wait 20 minutes
c:\satsin\delay.exe 20

:Netlink
rem -- Establish remote file mount disc f:
net link f: \\128.18.44.72\export/home/satsin/control
if exist f:\exist.txt goto Monitor
rem -- No remote mount, get default data
goto DataOps

rem -- Remote mount okay
rem -- Run BIT test for the record
c:\satsin\satsin\bitcal.exe

Monitor
:Monitor
rem -- Remote mount okay
rem -- Start monitoring program
c:\satsin\monitor.exe
if errorlevel 8 goto Exit
if errorlevel 7 goto Calibrate
if errorlevel 6 goto XPC
if errorlevel 5 goto Reboot
if errorlevel 4 goto PwrOff
if errorlevel 3 goto Pwrdown
if errorlevel 2 goto FTPD
if errorlevel 1 goto DataOps
if errorlevel 0 goto Exit
 rem -- Opening telnet session
call c:\satsin\ops\xpcrun.bat
goto Monitor

:FTPD
rem -- Opening FTP serving session on SATSIN
call c:\satsin\ops\ftpd.bat
goto Monitor

:Reboot
rem -- Rebooting SATSIN DAT
call c:\satsin\ops\reboot.bat
goto Monitor

:DataOps
rem -- Set time from GPS
call c:\satsin\ops\timeset.bat

rem -- Starting data session

:Tunetry
rem -- Tune receiver to optimize around satellite channel
c:\satsin\satsin\tune
rem -- No signal found
if errorlevel 1 goto Tunetry
rem -- Signal located
if errorlevel 0 goto Sigok
goto Monitor

:Sigok
rem -- Successful tune, link data output directory
net link g: \\128.18.44.72\export/home/satsin/data
c:\satsin\satsin\sigcw
rem -- Data session completed or interrupted
if errorlevel 6 goto Powermon
if errorlevel 5 goto Exit
if errorlevel 4 goto Netlink
if errorlevel 3 goto Cleanup
if errorlevel 2 goto Calibrate
if errorlevel 1 goto Tunetry
if errorlevel 0 goto Monitor
goto Monitor

:Calibrate
rem -- Run BIT test since receiver anomaly
c:\satsin\satsin\bitcal.exe
goto Tunetry

:Cleanup
rem -- Clear disc space since discs are full
c:\satsin\cleanup.exe
goto Tunetry

:Powermon
rem -- Wait for power to go down
c:\satsin\powermon.exe
rem -- Power restored before 15 minutes
if errorlevel 1 goto Start
rem -- Shutdown so unlink remote mounts
net unlink f:
net unlink g:

:Powerdn
rem -- Shut down UPS
c:\ups\powerdn.exe
goto End

:Exit
rem -- Shutdown so unlink remote mounts
net unlink f:
net unlink g:

:End
```

As soon as a remote mount has been established, the program MONITOR is called. That program checks every few seconds for the existence of a control file on disc F: named CONTROL.TXT. This file is the primary means by which the SATSIN is remotely controlled. The file contents are a single integer number, the value of which dictates how the SATSIN system will respond. The control flag values and their corresponding actions are listed in Table 3.

Flags 2 and 6 provide a means through which an operator has remote access to the DAT computer, per se. Using the FTP option, files (such as revised source code or command files) can be transferred to the DAT from any other computer with network access. In the Telnet serving mode (XPC), most command line functions (such as editing) can be accomplished, and most programs can be executed if they have no graphics output. Flag 5 is useful if, for example, changes are made in the system AUTOEXEC.BAT or the INIT.BAT files, and those changes need to be implemented. Flag 0 would be used only when an operator on site needs to regain console access from INIT.BAT. Flags 3 and 4 depend upon the eventual implementation of power control functions that are not currently available. Finally, flag 1 is the one that will be used routinely and repeatedly: it initiates the signal acquisition and data collection process.

Table 3. Control Flags in CONTROL.TXT

flag	*action*
> 8	return to MONITOR
7	force BIT calibration
6	open Telnet server session on DAT
5	force software reboot of the DAT
4	force UPS to power down Sun server
3	force UPS to power down receiver
2	open FTP server session on DAT
1	initiate data collection
0	force exit from INIT.BAT to console

Within a few seconds of when the file CONTROL.TXT is placed on the remote mount disc, it will be read by the MONITOR program, and then removed from the disc. During all subsequent signal tuning and data collection operations, the DAT periodically checks for the existence of a new CONTROL.TXT file to instruct it about changes in the operating mode. For example, a remote operator might want to end a data collection session in order to gain Telnet access to the computer. This would consist of creating an CONTROL.TXT file with contents set to 6, waiting for that file to be cleared by the DAT, and then starting a Telnet session.

If either the network (or the DIS computer) are not functioning, the DAT bypasses the MONITOR program and defaults to an operating mode that uses local parameters stored on its local (C:) disc. The default mode collects data on a continuous basis in

order to assure that no data are lost until the network connection is reestablished. Periodically, the DAT checks the network status and attempts to remount its remote disc on the DIS. The data collection process is reviewed in more detail below.

As is indicated in the listing of the INIT.BAT file, at the start of each new data episode the DAT system clock is set by a call to the GPS receiver. That device sends a continuous stream of GPS information from which the SETTIME.BAT file calls the program GPSTIME.EXE to extract the UT time and sets the system clock. The precision to which the clock is set is approximately 500 ms, although this can be improved if necessary by altering the routine operating mode of the GPS receiver.

All of the programs called by INIT.BAT provide some kind of logging information to the file to the file F:\REPORT.TXT (or if the network is not functional, C:\SATSIN\OPS\REPORT.TXT). A example of the REPORT.TXT file from a typical operation is shown in Table 4. Some of the responses shown in the table will be discussed in conjunction with the software functions described below.

Table 4. Sample REPORT.TXT file

```
Opened remote report file f:\report.txt
Opened remote mode file f:\signal.txt
950517 1000534 TUNE:
  carrier selected, 243741050
  snr   15.39 15.36 15.43 16.48 18.96 19.66 19.72 19.67
  noise 70.33 70.63 70.30 67.93 66.82 66.59 66.22 66.03
950517 1005574 :SIGCW start
950517 1005582 :SIGCW operator exit
950517 1156459 :SIGCW **NO SIGNAL, CHANNEL 0**
950517 1156459 :SIGCW **NO CARRIER**
950517 1158262 TUNE:
no carrier
 950517 1200131 TUNE:
no carrier
950517 1201345 TUNE:
 carrier selected, 243741100
  snr   21.37 20.20 21.09 22.35 23.85 -17.24 24.36 24.16
  noise 70.27 71.33 70.76 69.32 67.84 109.67 67.21 67.27
950517 1202368 :SIGCW start
950517 1415376 :SIGCW operator exit
```

3.2.2. Signal Tuning and Acquisition

At the start of each new data episode, the DAT searches for a useful satellite signal using the program TUNE.EXE. TUNE first reads a text file that includes the nominal signal parameters: the carrier frequency of the channel assigned for use at HAARP, the range and resolution of the tuning search process, and the required signal to noise ration for the signal to be considered. These parameters are in the remotely-mounted file F:\SIGNAL.TXT. The contents of that file are shown in Table 5. If the

network is not functioning, there is a local version of the file in the directory C:\SATSIN\OPS which the tuning program uses.

Table 5. Contents of typical SIGNAL.TXT file

value	*parameter*
243741050	nominal frequency, Hz
1000	search range, Hz
123	receiver IF gain, dB
20	minimum SNR threshold, dB

Because of the high eccentricity of the satellite orbit, the precise transmission frequency at any time can deviate significantly from the nominal assigned value. Therefore, it is necessary to initially tune over a range of approximately (1 KHz with eventual refinement to obtain tuning to within about 5 Hz of the carrier). The maximum received signal (if any) must be above a specified signal-to-noise threshold for the tuning to conclude and for control to be handed over to the data collection processes. The code requires that at least three receivers have adequate signals, and that all are at the same frequency. If this is not the case, an error flag is returned by TUNE and the tuning cycle is restarted. The signal threshold is included in the SIGNAL.TXT file, and can be adjusted to adapt to any particular field site or experiment demands.

The TUNE.EXE program also uses the magnitude of the spectral energy to verify that the gain settings of the NCI receiver are suitable for the signal received. The NCI receiver has a single gain control setting for all eight channels since the receiver inputs can be pre-balanced using gain and attenuation adjustments in the output stages of the antenna-mounted preamplifiers. As was discussed in section 3.1.2 above, the NCI receiver will normally be operating at its maximum gain setting of 123 dB. The TUNE.EXE program signal level check mostly protects against saturation above the -85 dBm limit. All receivers are scanned to determine proper function and the maximum signal magnitude. If necessary, the gain is then set to avoid receiver saturation (assuming a fading environment).

In the case that the TUNE.EXE program is successful in finding the same signal on at least three antennas, it prepares a local file (C:\SATSIN\OPS\OPERATE.TXT) that includes the tuning information and gain settings for the start of data collection. The typical contents of this file are shown in Table 6. Additionally, as noted above, the success or failure of the tuning process is reported by the TUNE.EXE program in REPORT.TXT, and includes the number of receivers detecting carriers, and at what frequency.

The source code for TUNE.C is included in the *SATSIN Software Manual* (1995).

Table 6. Contents of typical OPERATE.TXT file

value	*parameter*
243741000	measured carrier frequency, Hz
123	optimum IF gain, dB
20	minimum SNR threshold for data collection
950518 1841	time tag for file

3.2.3 Data Collection

After TUNE finds a signal, control is handed to the routine data acquisition program, SIGCW.EXE. At this point, the gain and frequency of the receiver are optimized and need to remain so during data collection. Maintaining a close track of the frequency is particularly important since the receiver bandwidth is narrow and the satellite signals that will be used at HAARP are always changing in frequency. The high eccentricity of the satellite orbit imparts a Doppler shift to the signal that changes by several Hz per minute: to roughly compensate for the long-term change in Doppler, the satellite itself retunes its transmitter every 163 seconds. The data collection program continuously monitors the signal frequency by computing the spectrum of the data from one receiver (nominally receiver 1), obtaining an estimate every 5 seconds. The average frequency over a series of 33 records is used to estimate the change in Doppler, and to derive a new tuning frequency that centers the carrier at close to 50 Hz in the receiver passband. The tuning of the receiver therefore occurs every 165 seconds, when an IEEE488 tuning command is issued by the DAT to the receiver.

The data collection process continues until there is either a change in the signal character, or an intervention of the operatior. At that point, the program exits and returns control to the INIT.BAT loop. Table 7 lists the conditions that can terminate the data collection, and how they are set.

Table 7. Data Collection Exit Conditions

flag	*action*	*origin*
5	shutdown to system command line	program if power loss or local operator input
4	retry remote NFS mount	program
3	disc full	program
2	perform BIT calibration	program if signal lost or operator input
1	retune after all signals lost	program
0	return system to idle	operator input

The signal level of all eight channels is also monitored during data collection. Under normal operations, the signal level changes only slightly over the approximately 2-3 hours of a typical satellite operational period, so any change in signal strength usually occurs simultaneously on all eight channels. A sudden drop in (or loss of) signal

indicates a switch from one satellite to another. When a switch occurs, both the signal frequency and the propagation geometry change, so a retuning is necessary and the data collection program exits to the INIT.BAT control loop. If the signal level for a particular receiver drops below the specified SNR threshold, it may indicate an antenna failure. If this occurs, it is logged in REPORT.TXT, and the data collection exits with a flag that then forces a noise-source BIT test to be run.

The DAT also digitally detects all channels of data in real time. The SIGCW.EXE program down-converts the low IF signal from the NCI receiver to in-phase and phase-quadrature baseband components. This quadrature detection is done digitally, which has significant advantages over detection in hardware. In a hardware detector, it is difficult to maintain balance and to avoid DC offsets in the quadrature samples. Digital down-conversion additionally assures that the channel-to-channel passband characteristics are exactly identical, although this is not a particular problem for the SATSIN application where the signals are always narrow-band.

Digital down-conversion of a low IF signal consists of mixing the signal with the sine and cosine of the local reference oscillator (50 Hz in the SATSIN case), and low pass filtering the two products to eliminate unwanted images. With 16 baseband signals, the filtering process puts a significant demand on the computing power of the DAT, so an efficient algorithm is mandatory. The recursive Butterworth cascaded 3-pole low-pass filter (cutoff of 30 Hz) is both efficient and effective. To illustrate the overall performance of the digital detector, Figure 6 shows the power spectra of eleven narrow-band carriers that have been down-converted from between 30 Hz and 70 Hz to baseband. As the figure shows, the strongest unwanted mixing products (near -10 Hz) are more than 50 dB below the peak of the carrier. As should be expected, the carriers beyond 25 Hz are near enough to the cutoff of the low-pass filter that their signal strengths decrease slightly. In normal operation, the SATSIN tuning algorithm maintains the carrier centered on the receiver passband, so the effect of the low-pass detector filter on baseband magnitudes is not of concern.

3.2.4. Data Output and Archive

The detected baseband complex samples from the detection process are accumulated and are output every 5 seconds. The sample rate for these data is 125 Hz which is more than adequate for statistical characterization of its intensity and phase. The data array is output in a binary record following an informational header record. The header record, shown in Table 8, includes time, housekeeping and other parameters important to the interpretation of the data.

The data collection program, SIGCW.EXE, write the data output records in two ways. One is the data archive file that is normally written on the remote mount disc drive, and will be used for non-real-time processing. To separate system control from data, the data are stored on the remote mount disc, G:. These files contain approximately 30 minutes of data (approximately 30 Mbytes in size and are numbered chronologically.

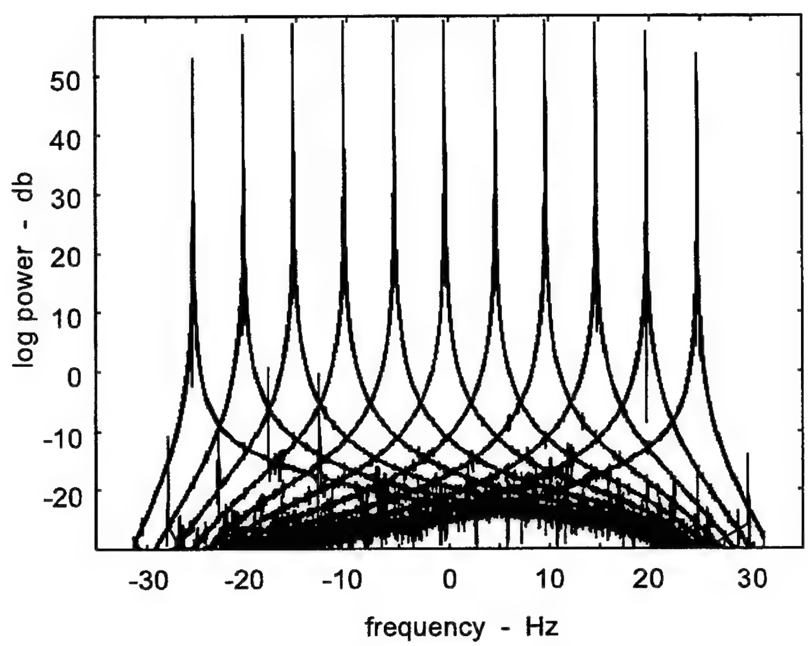

Figure 6. Eleven carriers at different frequencies illustrating the overall passband and low-level mixing products of the DAT digital detector.

Table 8. Format of Raw Detected Data Records

```
/* file: FREC8002.H (SATSIN DAT format) */

/* Output data file structure   */
#define NREC 20000

typedef struct
        {
        long    rectype;                /* record type index               */
        long    nheadbytes;             /* no. of bytes in headers (frec)  */
        long    nrecbytes;              /* no. of bytes in data array      */
        long    code_ver_date;          /* version date of data code       */
        long    boi_date;               /* begin date YYMMDD               */
        long    boi_time;               /* begin time HHMMSSS              */
        long    eoi_date;               /* end date YYMMDD                 */
        long    eoi_time;               /* end time HHMMSSS                */
        long    rx_freq;                /* receiver frequency              */
        long    rx_gain;                /* receiver gain (dB)              */
        long    rx_noise_offset;        /* receiver noise offset (dB)      */
        long    rx_noise_attn;          /* receiver noise attenuation      */
        long    rx_mode;                /* receiver mode                   */
        long    sample_rate;            /* raw data sample rate (Hz)       */
        long    sig_freq;               /* signal frequency (Hz × 10^5)    */
        long    sig_mod;                /* signal CW (0) or modulation     */
        long    ant_status[8];          /* number of receiver channels     */
        long    ant_signal[8];          /* signal levels (dB × 100)        */
        long    site_code;              /* site code                       */
        char    ant_loc;                /* antenna survey file name        */
        long    user_array[165];        /* (spares)                        */

 } FREC_STRUCT;

        float           data_reca[NREC];        /* data record array       */
```

The file number is automatically incremented every 30 minutes of data or when an operator changes the operating mode in any way. The file count is kept in the file C:\SATSIN\BOOKS\EXPNO.TXT.

In the abnormal case when a remote mount cannot be established, the data collection program writes only one 30 minute period of data to the local directory C:\DATA. It then branches out of the program to try and establish the remote mount, as is indicated in Table 2.

The DAT also ouputs the same records used for archive into a temporary file (TMPOUT.DAT) for use by the DIS for real-time processing and display. The file is overwritten every 5 seconds by SIGCW.EXE. Under normal operating conditions, this file is read by a program on the DIS computer and then deleted. The contents of the record are subsequently translated to Sun word formats and used for real-time processing and display purposes. This process is described in more detail below. So far as the DAT is concerned, the file is written or overwritten every 5 seconds, independent of the DIS process.

3.2.5. Calibration

The noise source in the NCI receiver provides a convenient and accurate means to assure that all receiver channels are functioning properly. A program (BITCAL.EXE) is available on the system to perform this function. It can be called by the operator using the CONTROL.TXT file, but is also called automatically if the signal in any particular receiver channel drops below the operational threshold.

The program initiates Test 2 in the receiver's BIT EPROM for a series of different noise input levels. It does this at a fixed receiver gain setting (120 dB) that is near that used for most data collection. In order to provide good statistical estimates of the noise, data at each signal level is collected for about 40 seconds. By comparing input and output, the program derives a transfer function for each channel of the receiver; from these, the receiver gain and linearity of each channel can be computed. These numbers are output to the REPORT.TXT file whenever the program is run. The expected response of the channels is also is programmed into the code, and any exceptions to the nominal performance are noted.

3.2.6. Data Management

The raw (detected) data archive files on remote mount disc G: or on the local disc C:\DATA can be accumulated for as long as disc space is available. During routine operations, they will be periodically archived to tape, discarded, or moved to the HDCC using the FTP network utility. Typically, the remote mount disk G: on the DIS will have space for a few days of data, so operator intervention need not be frequent. If there is an

extended period over which the remote NSF mount of the G: disc cannot be made, about two days of data can be archived on the system disc C:\DATA. Since SATSIN will be operated at a remote location, this assures that if there is a failure in the DIS, all data will be archived and can be recovered by offline processing.

In the unlikely case that either the remote G: or local C:\DATA discs have not been attended to and become full, the data collection program exits and the program CLEANUP.EXE is called. That program eliminates the oldest data files, and assures that there is adequate disc space for backup of at least 6 hours of new data. This process is repeated approximately every six hours until an operator intervenes to transfer, discard or archive the files.

3.3 DIS Computer Operations

In contrast to the real-time demands on the DAT, the DIS must use a multi-tasking environment since it manages the processing and display of data, and the ethernet communications to both the DAT and to HAARP. The operating system for the DIS is Sun Solaris 2.4.

3.3.1. Overall Operation

The DIS computer manages several tasks, among these are: (1) receiving control information from the HAARP Diagnostic Control Center for the management of both the DIS and DAT, (2) receiving raw data from the DAT computer as an NFS server, (3) processing of those data into statistical summaries of the heater-induced scintillation in netCDF format, (4) displaying the computed parameters and (5) allowing access of the HDCC to the raw and processed data using TCP/IP. Because these functions are independent and need to be done simultaneously, the DIS operates in a multitasking mode.

3.3.2. HDCC Control Information

As shown in Figure 3, the the serial routers connect the local network at the SATSIN site to the network at the HDCC. The data collection functions of the DAT can then be implemented using text files (such as CONTROL.TXT) set up by an operator at the HDCC. In order to be seen by the DAT on remote mount disc F:, control files need to be placed in the DIS directory /EXPORT/HOME/SATSIN/CONTROL.

The specific mechanism used to set up these DAT control files and to perform other tasks on the DIS (such as data archiving) have not yet been defined by the HDCC. However, they will be TCP/IP functions and are likely to use a combination of Telnet, FTP transfers and remote NFS mounts between the HDDC and the DIS. It should be

noted that the SATSIN system has been designed to be independent of the mechanism, per se, that is used for this control information.

3.3.3. Real Time Data Reception

As was described in Section 3.2.4, the DAT places a temporary file, TMPOUT.DAT, on its remote mount G: drive. On the DIS, this file appears in the directory /EXPORT/HOME/SATSIN/DATA. This file is independent of the chronologically-numbered archive data files that are stored in the same directory.

On the DIS, a background process (GETDAT.EXE) operates which waits for the file TMPOUT.DAT to appear, reads it, and then deletes it. It stores a sequence of these records, converted to Sun-compatible format, and adds them to one of two temporary files, TIMESIG1.DAT or TIMESIG2.DAT. These files are double-buffered by the code so that at any time, one of them has an 80 second span of complex baseband samples which are available for processing while the second file is filling. The data in these files overlaps by 40 seconds of data time, so the double buffering cycle time is 40 seconds. Section 3.3.4 below explains why 80-second overlapped data spans were chosen for the analysis goals of the experiment.

3.3.4. On-line Data Processing

The availability of signal beacons on satellites over the past two decades has led to a good understanding of transionospheric signal scintillation effects. In particular, there are statistical characterizations of the received complex signal that have become standard parameters with which to judge the effects of ionospheric electron density irregularities (*Fremouw et al.*, 1978). The processing code in the DIS computer provides these characterizations, and it is a significant task when data from eight receiver channels has to be processed.

A primary calculation is that of the intensity and (in the case of CW data) the phase spectra of the received signal. Computation of these spectra demands that the input times series be stationary; in the case of high-latitude effects and the orbit of the satellite sources used at HAARP, this is typically satisfied with a minimum analysis period of about 80 seconds. This time span is also the same as that used to analyze data from previous high-latitude experiments (e.g. *Basu et al.*, 1983), so all of the SATSIN processing uses data spans of this length. In the code that will be running routinely at HAARP, these 80 second data spans are overlapped by 40 seconds, so that a statistical summary will be available to the HDDC every 40 seconds.

The specific processing procedures that the DIS uses are the same as were developed for the DNA HILAT experiment (*Fremouw et al.*, 1983); these have become the *de facto* standard for most complex scintillation signal processing. The complex baseband time series for each receiver is converted to intensity and phase, windowed, and

the spectra of each computed in place using the FFT. From the spectra, two basic first-order parameterizations of the signal are derived. The first of these is the Briggs-Parkin S_4 index (*Briggs and Parkin*, 1963), which is the normalized standard deviation of signal intensity. It defines the degree to which the intensity of the received signal is disturbed by the propagation process, and is a useful indicator of the level of scattering. The second parameter derived is the rms phase deviation, Φ_{rms}, an indicator of the amount of phase scintillation. The phase deviation can be large at high latitudes, even in the absence of intensity fading and is a more ambiguous parameter than S_4 since the phase spectrum includes contributions by very large (e.g. tidal) variations in total electron content. For SATSIN purposes, the Φ_{rms} index magnitude is limited by the 80-second span of the data used to compute the phase spectrum.

The shape of the phase spectrum (and to some degree that of intensity) is also of interest because it provides a near-direct mapping of the spectrum of the ionospheric irregularities (*Rino*, 1979). For this reason, a decimated version of the log-log phase and intensity spectra are included among the DIS output parameters.

In addition to these time series characterizations of the signal, the DIS performs a correlation analysis of the data from the eight SATSIN receivers. This is the major computing task for the DIS, in that many hundred FFTs are involved in the analysis. The technique that is used for routine operations is the so-called intersection method (*Rino and Livingston*, 1982), based upon the work of *Armstrong and Coles* (1972). The method derives the elongation and motion of a measured correlation ellipse at the receivers based upon the intersections among the various auto- and cross correlation functions of the time series from the eight receivers. The velocity measured by the technique has been shown to agree well with that derived from quiet-time bulk plasma drift measurements made by incoherent scatter radar (*Livingston and McCready*, 1992).

An operating version of the real-time processing code (SSSTAT.EXE) is included in *the SATSIN Software Manual* (1995).

3.3.5. Data Archive and Availability to the HDCC

Per HAARP requirements, the measured statistical parameters derived from the DIS processing are made available on the network in the form of a netCDF structure. The preliminary format of this structure is shown in Table 9, and includes time-tagging and SATSIN system housekeeping information, as well as the signal parameterizations reviewed above. As the definition of the HDCC computer system and operations proceed, certain features of this format may be altered to match that of other diagnostics.

The real-time data processing program (SSSTAT.EXE) generates and outputs the netCDF files.

Table 9. Format of the Processed Parameter netCDF File

```
// file sats001.cdf:initial SATSIN netCDF output file CDL

netcdf    satsin_001          {

dimensions:
          chan = 8, freq = 20, x = 100, y = 100, time = unlimited;

variables:
// observed signal
          float mean(time, chan);
                    mean:   long_name          = "mean signal level";
                    status: units                          = "db";
          float status(time, chan);
                    status:   long_name        = "channel status";

// first-order statistics
          float S4(time, chan);
                    S4: long_name    = "intensity scintillation index";
                    S4: valid_range = 0.0, 1.2;
          float prms(time, chan);
                    prms:   long_name          = "standarad deviation of phase";
                    prms: units                            = "radians";

// signal power spectra
          float int_spec(time, chan, freq);
                    int_spec:          long_name          = "intensity power spectrum";
                    int_spec: units                       = "S4 squared units/Hz";
          float phase_spec(time, chan, freq);
                    phase_spec:        long_name          = "phase power spectrum";
                    phase_spec: units                     = "radians squared/Hz";

// correlation pattern fits parameters
          float anios(time);
                    anios: long_name           = "correlation pattern aniostropy";
          float orient(time);
                    orient: long_name                     = "correlation pattern orientation";
                    orient: units                         = "azimuth degrees";
          float velocity(time);
                    velocity: long_name        = "correlation pattern velocity";
                    velocity: units            = "m/s";

// correlation ML fit
          float surface(time, x, y);
                    surface: long_name         = "correlation surface pattern";
                    surface: valid_range       = -0.5, 1.5;
```

Table 9. (cont'd)

```
// housekeeping
        long date_start;
                date_start: units           = "yymmddd";
        long date_end;
                date_end: units             = "yymmddd";
        float time(time);
                time: units                                 = "seconds UT";

// receiver settings
        float   frequency;
                frequency: long_name        = "receiver frequency"
                frequency: units            = "MHz";
        float   attenuation;
                attenuation: long_name      = "receiver attenuation"
                attenuation: units          = "db";

// experiment configuration
        char layout;
                layout: long_name                           = "antenna location table";

data:

// spectral frequencies equispaced in log Hz
                freq =   -2.0, -1.8, -1.6, -1.4, -1.2, -1.0,
                           -0.8, -0.6, -0.4, -0.2, -0.0,  0.2,
                            0.4,  0.6,  0.8,  1.0,  1.2,  1.4,
                            1.6,  1.8;
}
```

3.3.6. Data Display

Although the DIS will routinely operate at a remote and unmanned site, displays of derived statistical parameters will be available on the DIS. Because these displays will utilize the data in the netCDF files, the same displays will be available on the server at the HDDC to view the SATSIN data.

Prototypes of the DIS displays are shown in Figure 7, as they might be appear under Motif. They include:

(1) the signal intensity and phase time series for one of the SATSIN receivers,
(2) the accumulated first-order statistics for intensity and phase,
(3) the accumulated estimates of irregularity anisotropy and drift,
(4) the power spectral density of intensity and phase variations, and
(5) a map display of the contours of constant correlation derived from the antenna array.

Development of the operating display software is awaiting a decision on what graphics widget set is chosen by the HDDC. When that choice is made the specific features of the displays and their control menus will be defined.

3.4. Power Interruption Handling

The DIS computer periodically polls the system UPS using a 30-second crontab process to sense if site power has been lost. If this does occur, a control flag is set for the DAT via CONTROL.TXT to instruct it to shut down data collection. It also prepares itself for a graceful shutdown to assure that the integrity of the UNIX file system is not lost.

The UPS will maintain power to the computer and the receiver synthesizers as long as possible. By powering the synthesizers, frequency stability of the RF system is continued, so that data acquisition can resume as soon as possible after power is restored. If an outage extends beyond about 45 minutes, the DAT, which also monitors the UPS, will shutdown it down to avoid battery damage.

When power is restored after an extended outage, the DIS will reboot to its normal state. On the DAT, the severity of the outage will be recognized and the control file INIT.BAT will delay the data collection process for about 20 minutes. That assures that the receiver synthesizers have warmed up and are stable prior to any data collection.

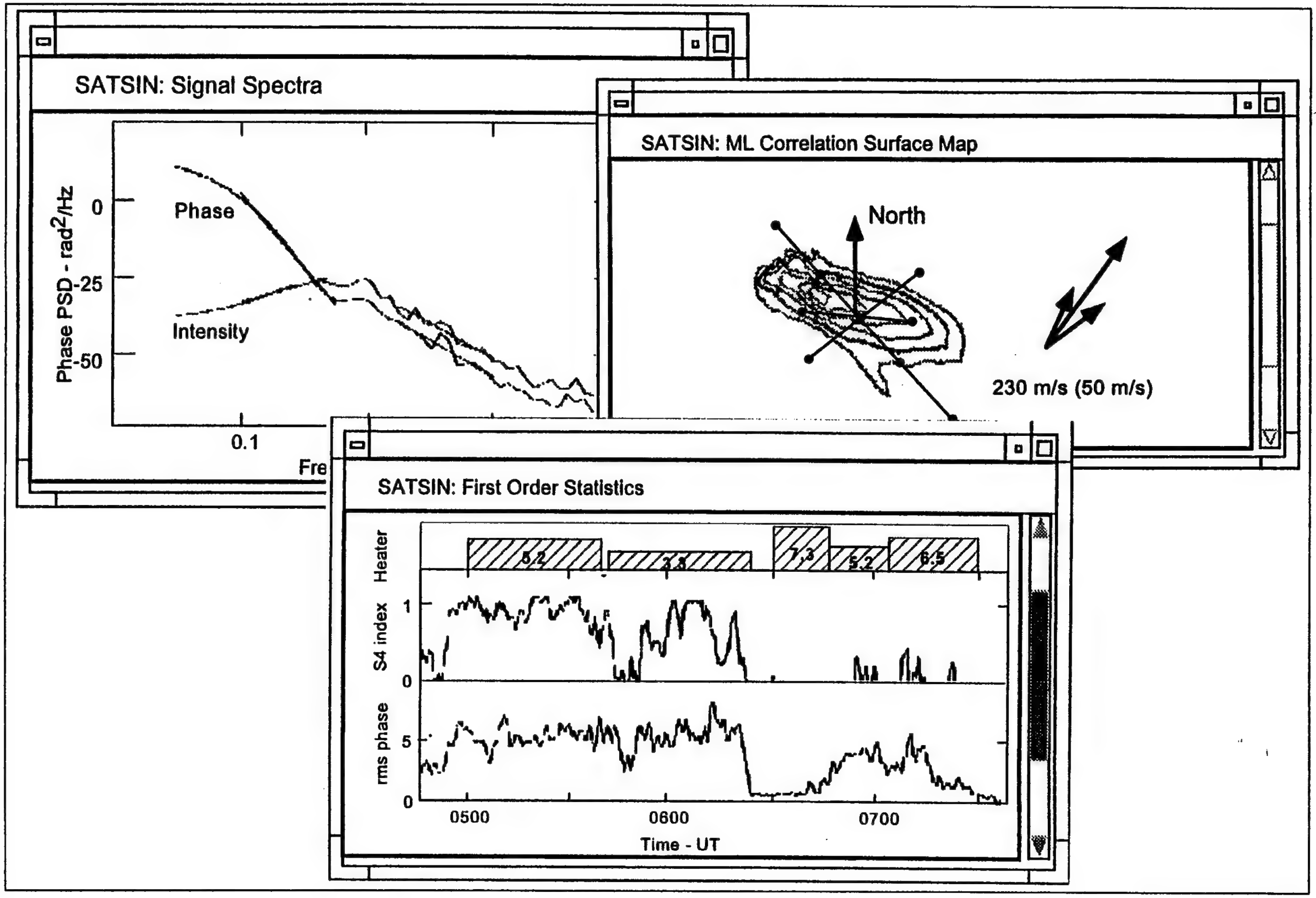

Figure 7. Prototype Motif displays on the DIS

4. FIELD OPERATION

Unpacking, installation, and check out of the SATSIN electronics requires approximately four hours. Another three hours are required to fabricate the eight helix antennas. It is difficult to define the time required to install the cables and place the antennas, since this depends the conditions at the particular site. The only installation at a remote site that used all eight antennas required something less than two days for cable and antenna installation under winter conditions, but with cooperative terrain.

4.1. Electronics Hookup

The SATSIN system electronic components are shipped in four containers. The receiver and two computers are rack mounted in three separate cases, in the arrangement shown in Figure 8. The monitors for the DAT and DIS computers are shipped in a separate container. Basic installation of the system consists of cabling the receiver and computers, installing the GPS receiver, and hooking the antennas to the receivers.

1. Once the receiver racks are in place and in the order shown in Figure 8, power should be applied to its plug strip in order to allow warm up of the receiver synthesizers. If the light on the Preamplifier Power Chassis is lit, turn that chassis off.

2. Make the connections between the DAT computer and the receiver as shown in Figure 9. These consist of the IEEE488 cable for receiver control, and the eight coaxial lines bringing the low IF from the receiver into the Analog Interface Chassis. The eight signal lines are of uniform length and remain attached to the receiver at all times.

3. Connect the ethernet cables between the DAT and DIS computers using the cable already attached to the DIS, as shown in Figure 9. The serial router is installed in the same container as the DIS, and remains attached to the DIS BNC tee at all times. A cable as long as about 50 feet can be used for the computer/computer connection if necessary to accommodate arrangements at a particular site.

4. Attach the telephone cable from the serial router to the local telephone service. The cable supplied is 50 feet long, but longer ones can be used if necessary.

5. Attach the two computer monitors and keyboards to the DAT and DIS computers, and plug the monitors into the plug strips for their respective racks.

6. Plug the two computer plug strips into the back of the UPS and plug the UPS into the mains.

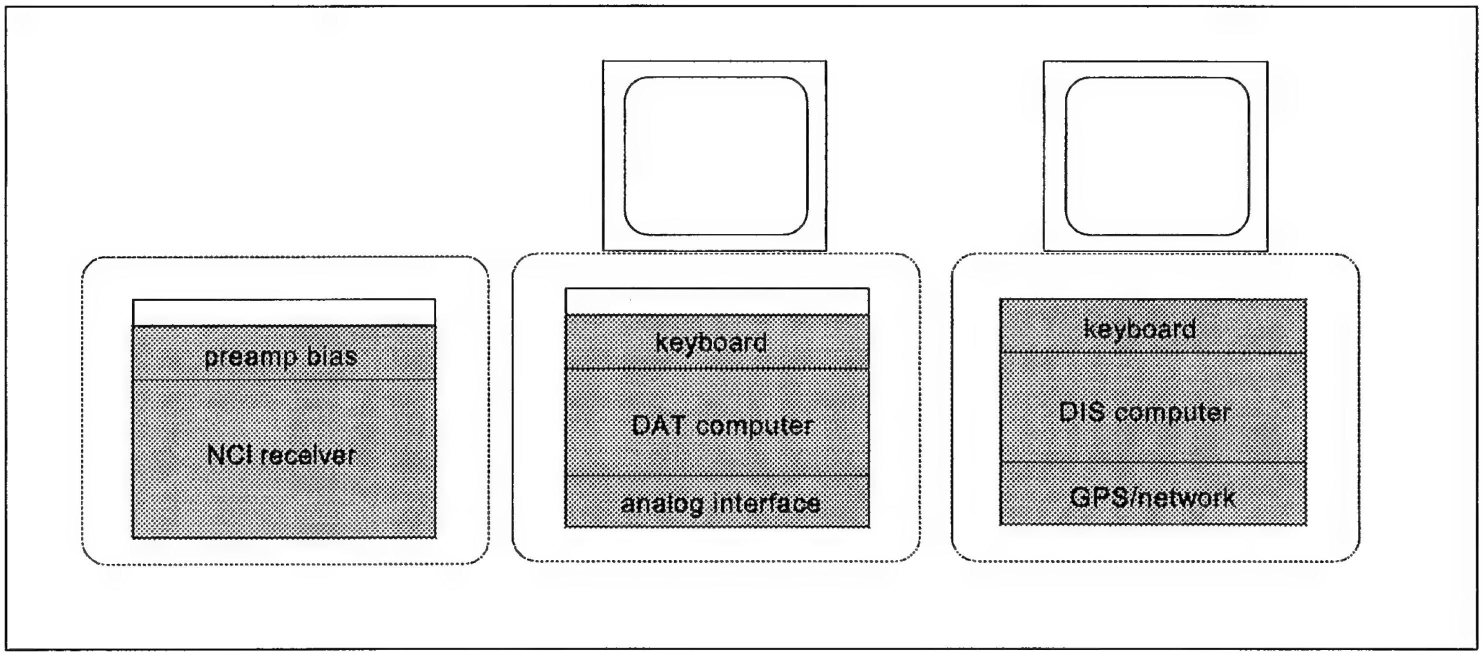

Figure 8. SATSIN equipment enclosures

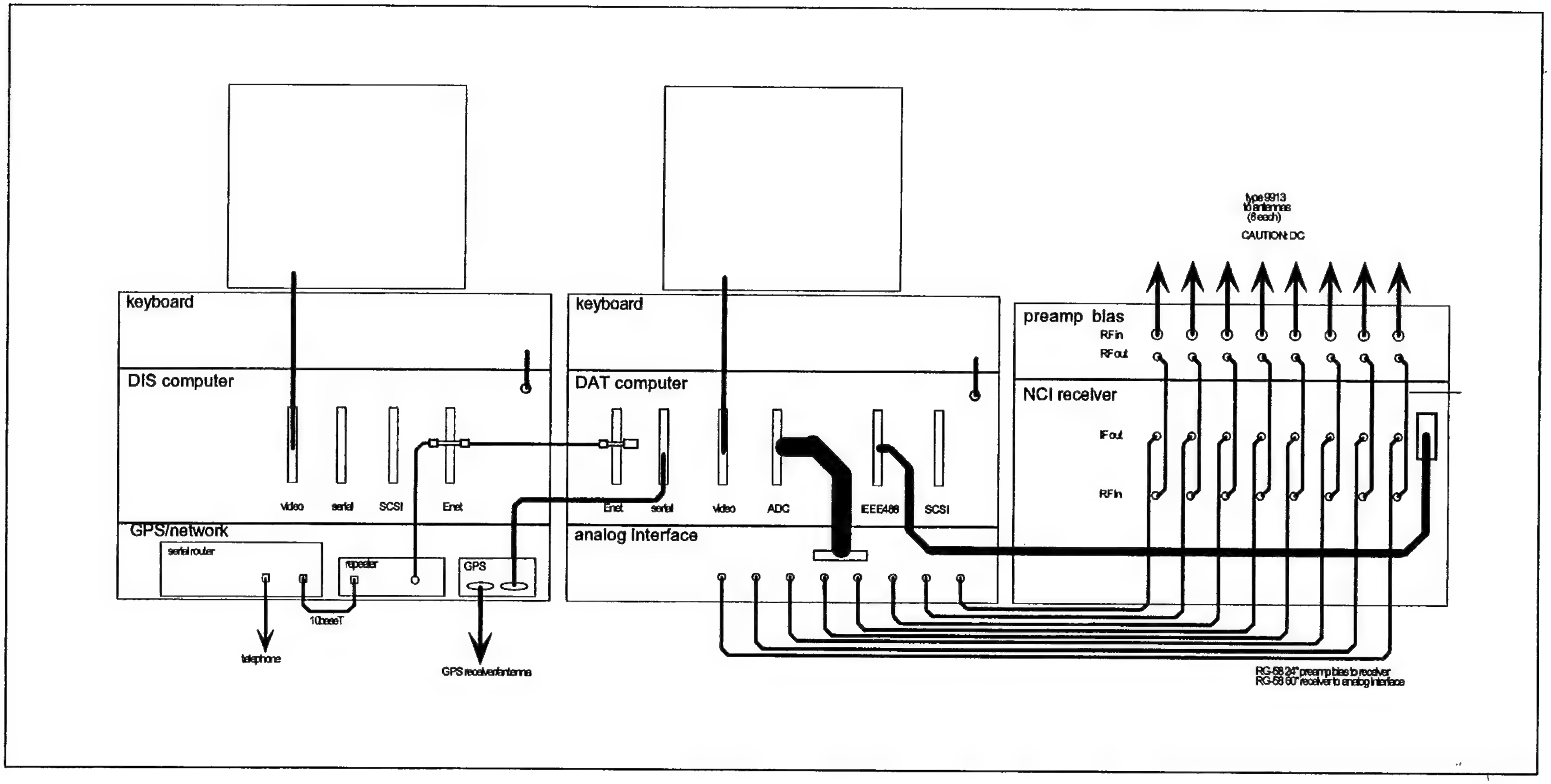

Figure 9. SATSIN equipment interconnections

4.2. GPS Receiver Installation

The GPS receiver is used to assure very accurate time-tagging of the processed data. Its installation consists of installing the receiver outside the site and cabling to the data systems.

1. Screw the GPS receiver onto the 4 foot plastic mounting pole supplied. The plastic pole is designed to mount with U-bolts to an outside mounting fixture. That fixture is normally a vertical wooden pole that positions the receiver with good visibility to the horizons in all directions, and a few feet above any surrounding structures.

2. Attach the cable to the GPS receiver and mount the plastic pole to the outside mounting fixture. Route the cable in to the data system and attach it to the DB9 connector on the rear of the DIS chassis.

4.3. Receiver Function Checkout

Check-out of the receiver consists of verifying the function of the receiver using its power-on BIT test function. The front panel controls for the receiver are identified in Figure A.2.

1. Power up the UPS using the switch on the front.

2. Power up the NCI receiver rack using the switch on its power strip. The receiver will go through a self-test sequence with its TEST light illuminated. Wait until the TEST light goes out, which takes approximately 40 seconds.

3. Select the AUTO mode from the rotary switch on the receiver.

4. Press the RESET button on the front of the receiver. The TEST light should light, and the LCD display will indicate channel-by-channel progress through the receiver's built-in test function. If any faults (e.g. gain offsets) are noted, the FAULT light will light. If this happens, press the RESET button again on the front panel and repeat the test. If errors remain, the anomaly should be noted. However, if there is a malfunction, it will also be found and reported in more detail when the routine data collection software is run.

4.4 DIS Network Function Checkout

Check-out of the DIS computer consists of assuring proper boot up and verifying the functionality of the local network.

1. Power up the DIS computer rack using its plus strip switch. The computer will boot to a command prompt after approximately one minute. The commentary for that boot sequence is listed as Table A.2 in the Appendix. Note any exceptions to the boot process. Of particular concern are indications that the system was not properly shutdown prior to loss of power.

2. Type NETWORK on the DIS computer, which will send an TCP/IP "ping" to the serial router to confirm network function. If the test is unsuccessful, the network connections should be rechecked, and the test sequence repeated. If the telephone line to the HDCC is connected, it also tries to "ping" that address. Typically, the remote ping will complete in about 60 seconds, but failure of this test does not necessarily indicate a problem with the local network function or the serial router.

4.5 DAT GPS/Network Function Checkout

Check-out of the electronics consists of verifying the function of the receiver using its BIT test function, booting the two computers, and verifying the functionality of the local network and GPS receiver.

1. Power up the DAT computer using the switch on the plug strip for its rack, and the computer will boot up. The commentary for that boot sequence is listed as Table 3 in the Appendix, and any exceptions should be noted.

2. The boot completes with a prompt that needs to be responded to within about 60 seconds. Type N to the prompt to get to DOS. If not responded to, the system will start its routine data collection mode will start.

3. At the DOS prompt on the DAT, type TIMESET. Within about 15 seconds, the computer should report that the system time has been synchronized to GPS time. The TIMESET.BAT file tries five times to set the time; if it is not successful, the installation of the GPS receiver is incorrect.

4. Type NETWORK on the DAT computer, which will send an TCP/IP "ping" to the serial router to confirm network function. If the test is unsuccessful, the network connections should be rechecked, and the test sequence repeated.

4.6. Antenna Fabrication

The helix design allows relatively straightforward assembly of the units, although care should be taken to obtain the proper direction of rotation for the element (steps 2-3). The sequence is repeated for all of the eight antennas.

1. Referring to Figure 2, attach the preamplifier assembly to the disc using three screws so that the preamplifier input port (banana jack) is up. As shown in the figure, the ground plane disc mounts with the outside lip downward.

2. Install the element supports in the mast, starting with the first hole up from the SMA connector. Facing the SMA connector, the element support screws into the hole from the right hand side, as indicated in Figure 2. Subsequent element supports are screwed into the mast so that they will support a right-hand rotation of the element outward from the SMA connector. The nylon nuts should be used to secure the supports to the mast.

3. Install the element on the completed support structure, trying to maintain a smooth radius for the helix. Another set of nylon nuts should be applied to secure the element to the supports.

4. Carefully insert the antenna assembly into the preamplifier input port, and secure it there using the set screw on the neck of the preamplifier assembly.

4.7. Antenna Installation

The pattern in which the SATSIN antennas are laid out is crucial to the quality of the spaced-receiver measurements. The suggested pattern for routine operations at HAARP is shown in Figure 10, although the optimum orientation of the pattern will be determined when the system is installed. The long dimension of the pattern is oriented to lie along a mapping of the F region magnetic field line at the propagation penetration point.

The spacing of the antennas along the long dimension of the pattern should be maximized, and will be limited only by the 1000 foot rolls of cable that will be used for their installation. A cable spooler is shipped with the SATSIN system to facilitate rapid installation of the cable.

1. Verify that the power to the Preamplifier Power Chassis is off before connecting any antenna cables, either at that chassis or out at the antennas.

2. A preliminary survey of the antenna locations should be made, according to the installation map for the site.

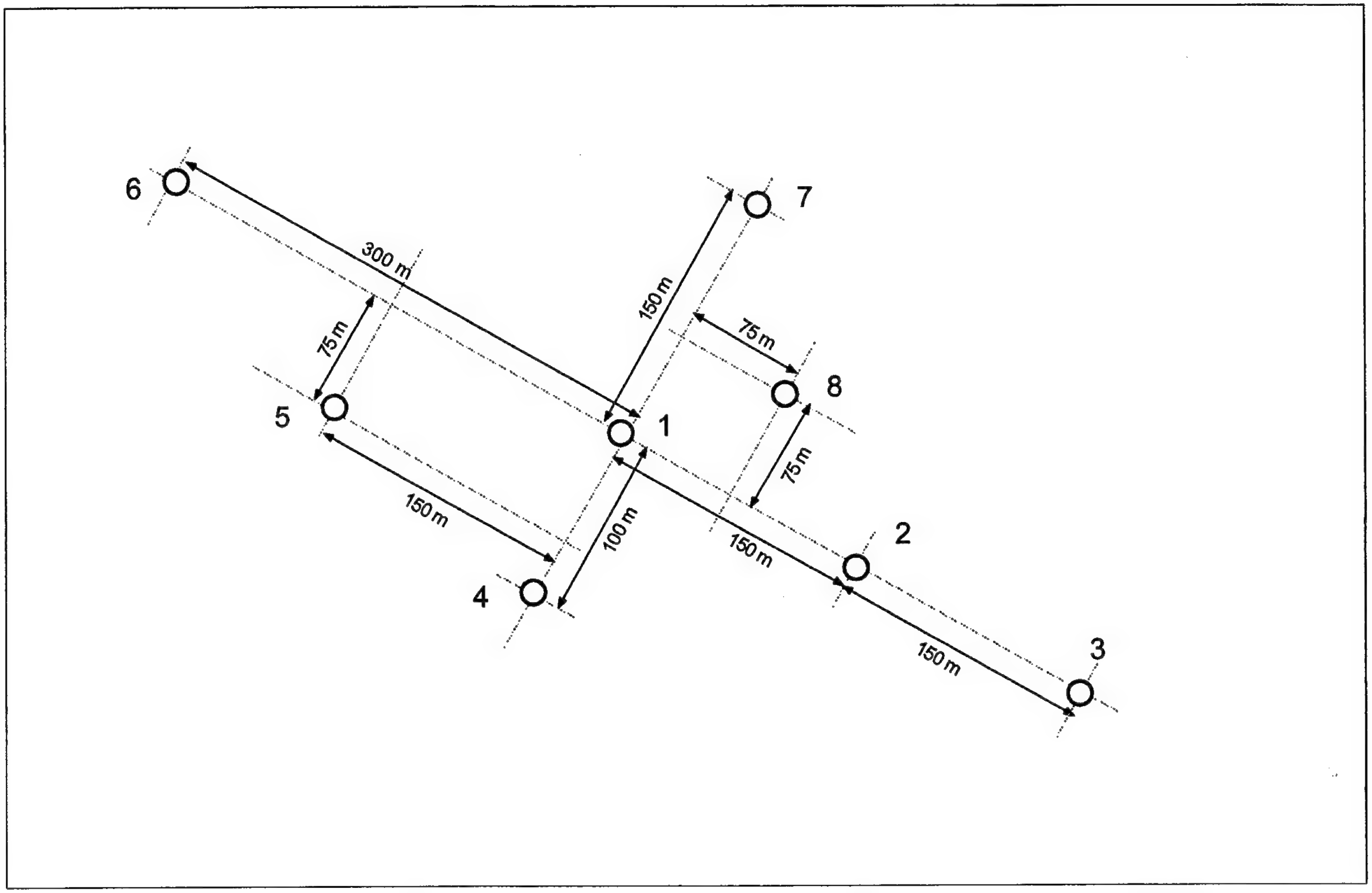

Figure 10. Nominal antenna placement for SATSIN at HAARP

3. Run the cables to the antenna locations. The cables supplied are a low-loss type that uses a solid center conductor, so care should be taken to avoid any kinking of the cable.

4. Each completed helix antenna mounts on an aluminum tripod assembly as shown in Figure 2. For long term installations, spikes should be placed through the holes in the tripod feet and into the ground.

5. The preamplifier assemblies supply either 20 or 40 dB of gain, with the higher gain designed to offset the longer cable losses. Install the completed antennas on their appropriate tripod stand and secure it using the wing nuts supplied. Attach the antenna cables to the preamplifier assembly.

6. When all cables are in place and are attached to the antennas in the field, attach the other end to the Preamplifier Power Chassis. When all antennas are connected apply power to the Preamplifier Power Chassis using the switch on its front panel.

4.8. DAT Data System Checkout

Once the antennas are connected and powered up, a simplified version of the system calibration and tuning routines can be used to verify that the system is operating, and that signal levels are near the optimum operating range.

1. From the DOS command prompt, type CHECKOUT, which starts a .BAT file of the same name. This first calls the BIT calibration routine to verify that the receiver itself is operating nominally. The BIT sequence through all signal levels takes approximately 4 minutes. The .BAT file then calls the tuning program (TUNE.EXE) which goes through a routine signal acquisition; the process takes approximately 60 seconds.

2. Results from both the calibration and tuning processes are reported in the local C:\SATSIN\OPS\REPORT.TXT file, which is automatically scrolled to the computer screen. The results should be similar to those listed in Table 10. The calibration results indicate the linearity and gain of the individual receiver channels. If any values exceed specification, they are reported as such. The tuning results list the frequency of the carrier detected and the signal-to-noise ratio and noise for the eight receivers. The noise level reported should be in the range of 60-70 dB, well above the minimum 55 dB that is reported when the preamplifiers are powered off or disconnected. The SNR should have a minimum value of about 15 dB; if it is below this, but the noise level appears to be correct, it is possible that the satellite signal is turned off. In such a case, repeat the same test at some later time

3. If an individual channel preamplifier does not appear to be functioning, it should be straightforward to isolate the problem. The most likely reason for malfunction is the connector center pin, so that should be initially inspected. Beyond that, a first step would be to swap cables from different, functioning antennas, to the channel having difficulty. The preamplifier enclosures can also be easily swapped.

5. REFERENCES

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APPENDIX: HARDWARE/SOFTWARE COMPONENT SPECIFICATIONS

SATSIN Receiver:

Description:	Special purpose 8-channel UHF receiver system designed to minimize phase jitter and noise, and interchannel phase drifts.
Manufacturer:	NCI Systems Noise Com, Inc. E. 49 Midland Ave. Paramus, N.J. 07652
Model:	NCI Model 4116
S/N:	001
Specifications:	attached as Table A.1
Documentation:	*SAT SIN Receiver NCI 4116 Operating Manual* October, 1992
Other:	block diagram attached as Figure A.1 front panel diagram attached as Figure A.2 back panel diagram attached as Figure A.3 dip switch settings attached as Figure A.4

Table A.1. NCI Receiver Specifications

Frequency Range:	240 MHz - 245 MHz
Tuning Increment	1 Hz
Tuning Accuracy	< 1 part in 10^8
RF Input Bandwidth	< 10 MHz
Noise Figure	< 5 dB
Dual Conversion Type	High side L.O.
1st IF	21.4 MHz
1st IF Bandwidth	30 KHz
Image Rejection	> 60 dB
2nd IF	10 Hz - 100 Hz
Upper Sideband Rejection	> 25 dB
Intermodulation Rejection	> 60 dB for two -50 dBm signals offset by 50 KHz
Gain Range in Voltage	60 dB - 123 dB
Gain Accuracy	± 2 dB
Gain Step Size	1 dB
Gain Step Accuracy, Gain < 92 dB	± 0.25 dB
Gain Step Accuracy, Gain > 92 dB	± 0.50 dB
Phase Jitter	< 5 degrees rms
Phase Drift	< 5 degrees/min for < 5° C Air Change
Output Bandwidth 3 dB	10 Hz - 100 Hz
Output Voltage	> 25 V peak-peak into 10K Ohms
Output Impedance	< 100 Ohms
Linearity	< 0.50% Total harmonic Distortion at 7.75 Vrms
Gain Balance Between Channels	< 2 dB
Gain Drift Between Channels	< 1 dB/min for < 5° C Air Change
Phase Jitter Between Channels	< 2 degrees rms
Phase Drift Between Channels	< 2 dB/min for < 5° C Air Change

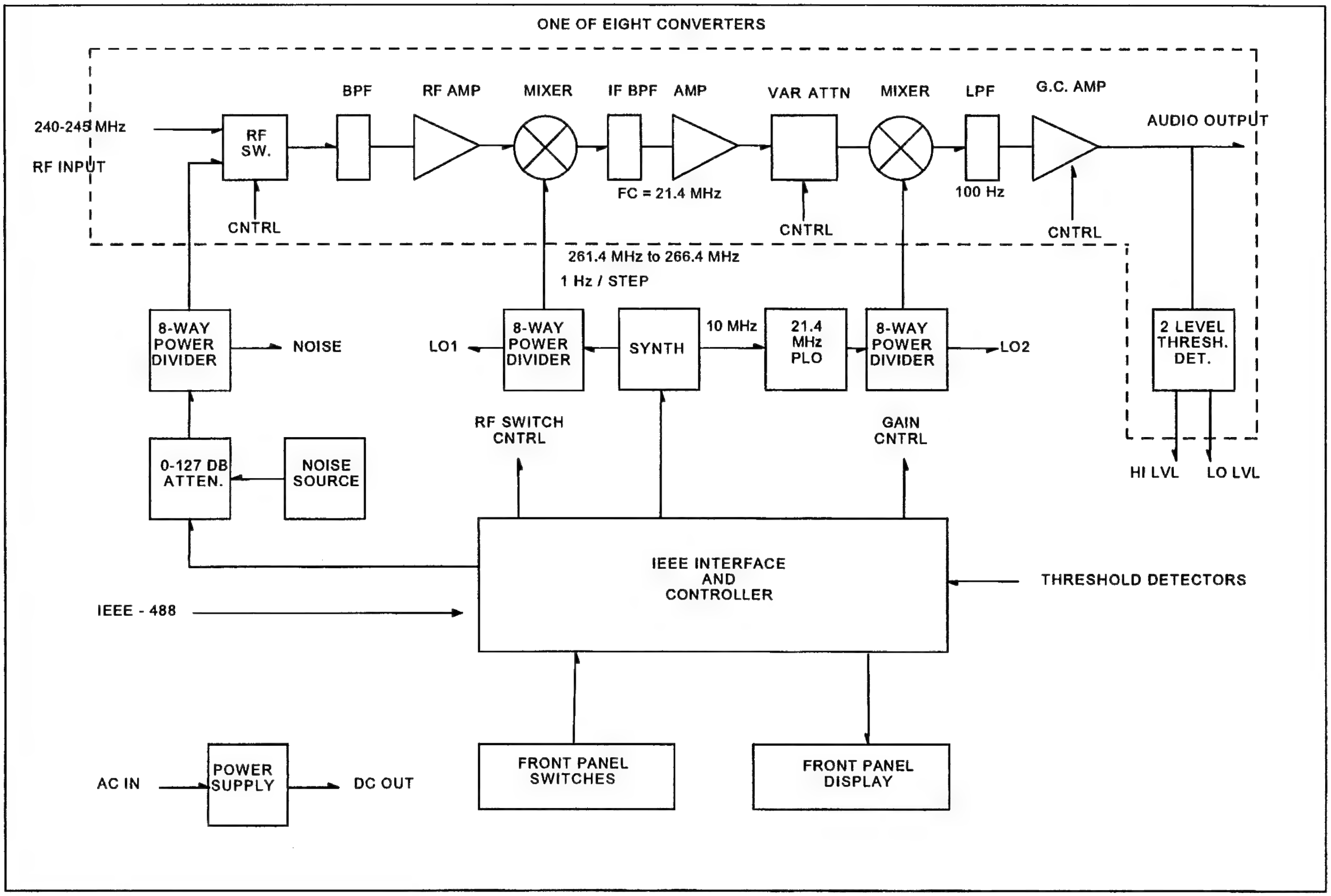

Figure A.1. NCI receiver block diagram

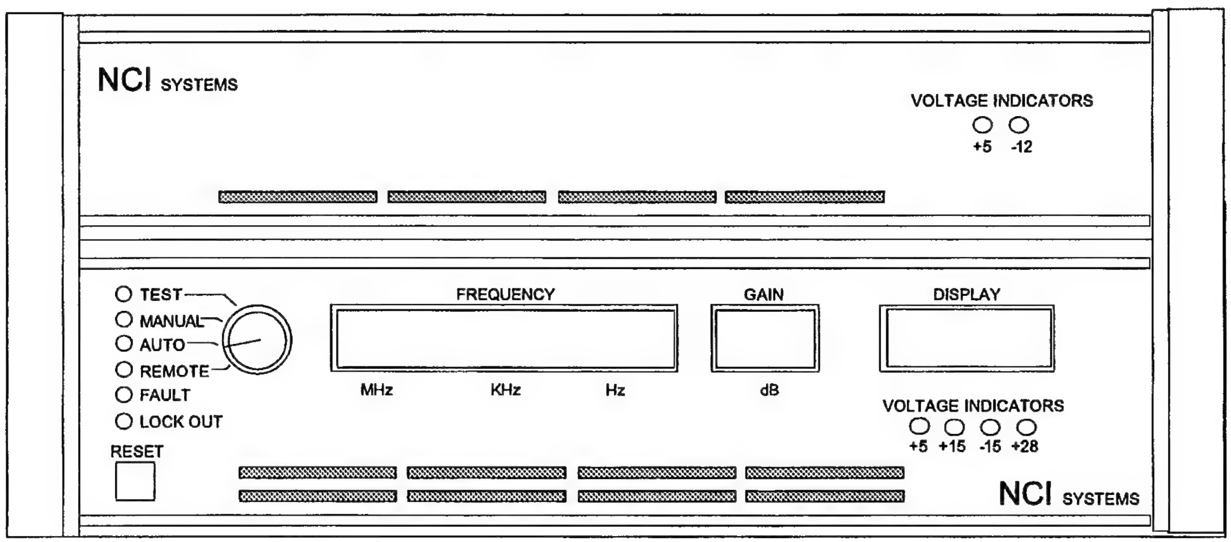

Figure A.2. NCI receiver front panel

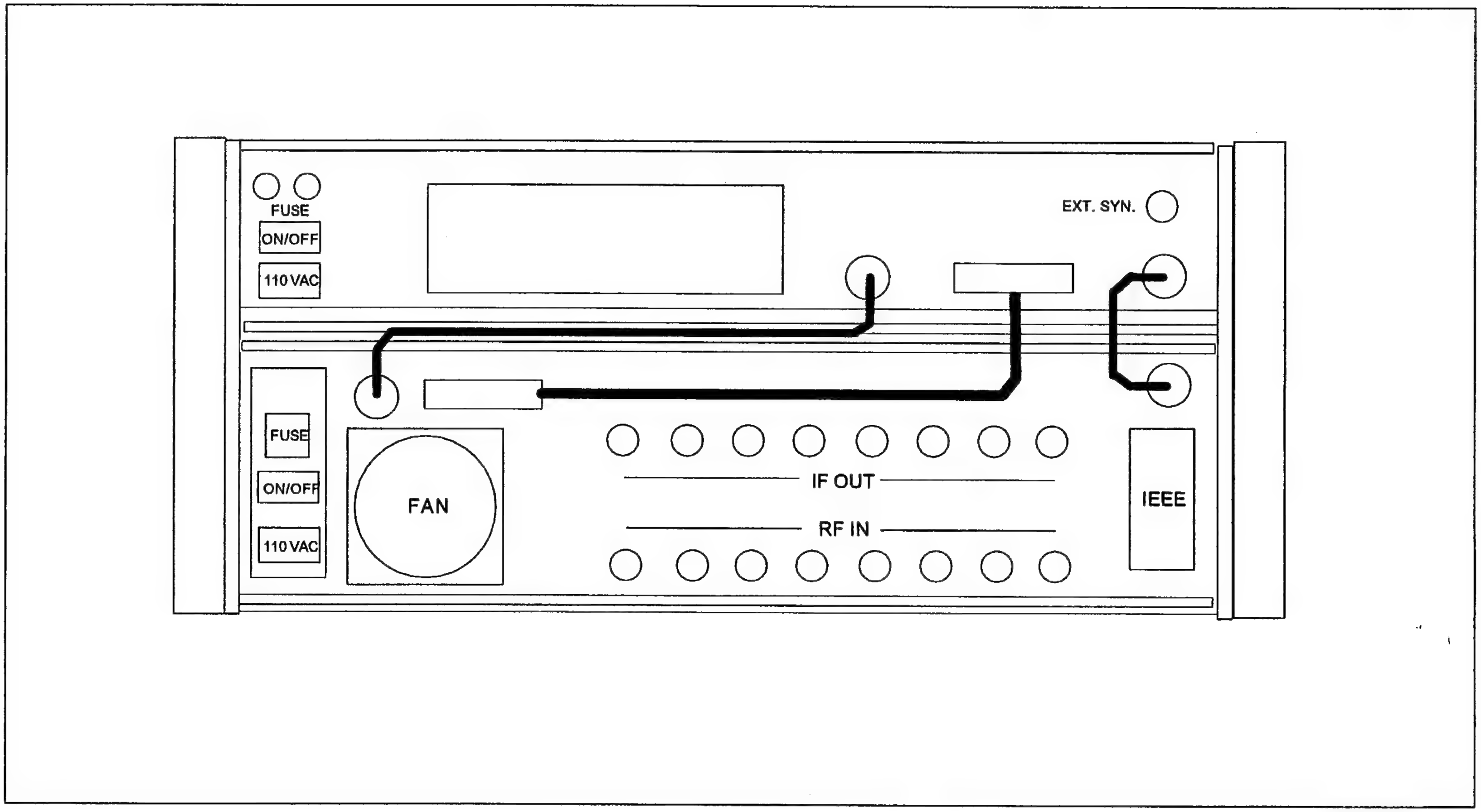

Figure A.3. NCI receiver back panel

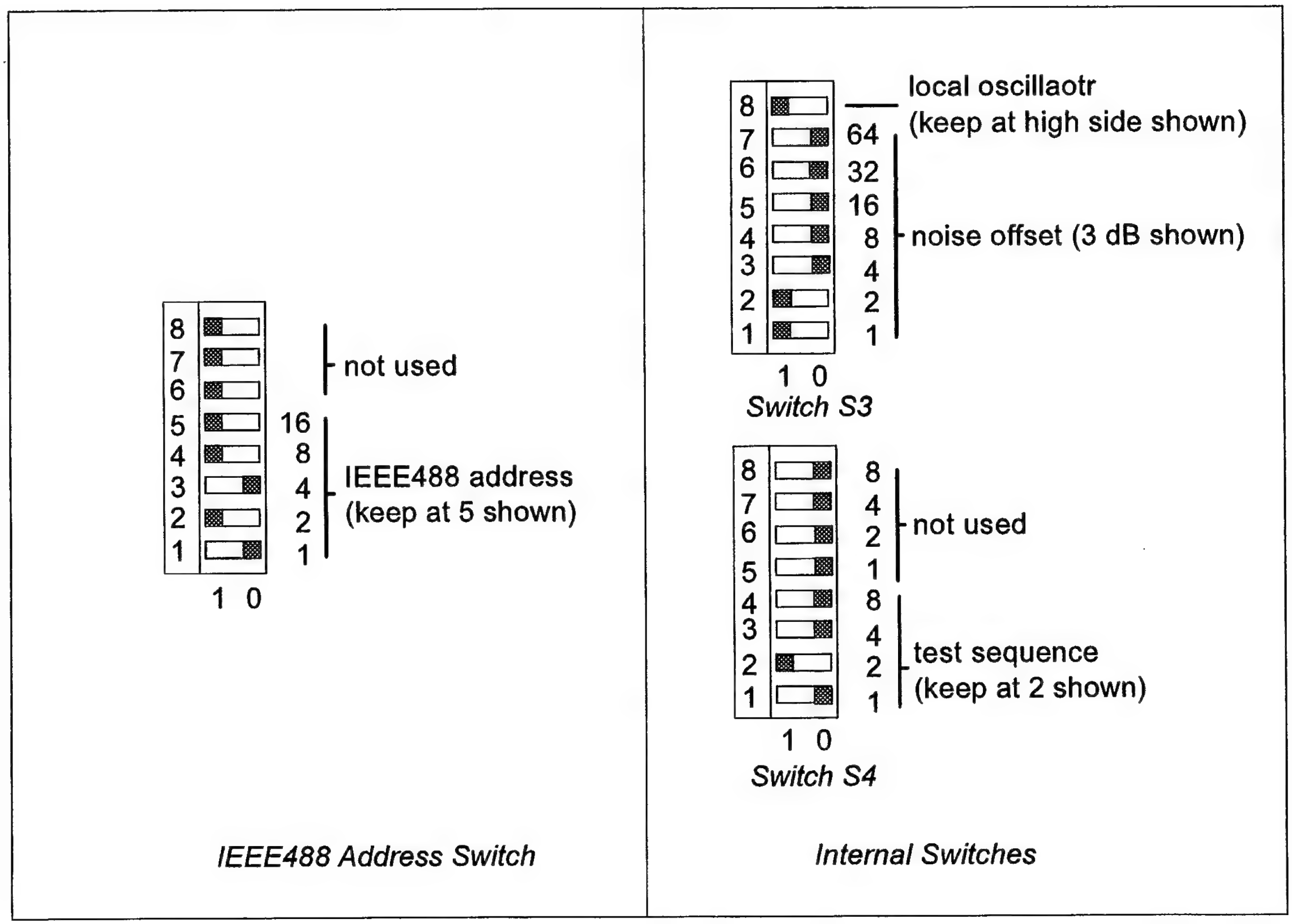

Figure A.4. NCI receiver dip switch settings

Helix Antenna:

Description:	Portable UHF helix antenna with built-in preamplifier assembly.
Manufacturer:	SRI International
Model:	--
S/N:	001- 008
Specifications:	*Specification for SATSIN Antenna* SRI Memo, June 1992
Documentation:	*SATSIN System Manual* (this document)
Other:	preamplifier and filter descriptions below overall antenna mechanical diagram attached as Figure 2 bias tee circuit attached as Figure A.6 preamplifier housing mechanical drawing attached as Figure A.7 preamplifier module layout attached as Figure A.8

Preamplifier Modules:

Description:	UHF GasFet low noise preamplifier with built-in bias tee.
Manufacturer:	Advanced Receiver Research P.O. Box 1242 Burlington, CT 06013
Model:	P240-250-VDC-SMA-CHOKE
S/N:	various
Specifications:	20 dB gain 250 - 260 MHz bandwith ±0.1 dB
Documentation:	manufacturer's data sheet delivered with SATSIN system
Other:	--

Preamplifier Bandpass Filter Modules:

Description:	UHF bandpass filter.
Manufacturer:	TTE Inc. 2251 Barry Ave. Los Angeles, CA 90064
Model:	KC4-243-10M-50/50/613A
S/N:	various
Specifications:	10 Mhz 3 dB bandwidth 243 MHz center frequency
Documentation:	manufacturer's catalog
Other:	--

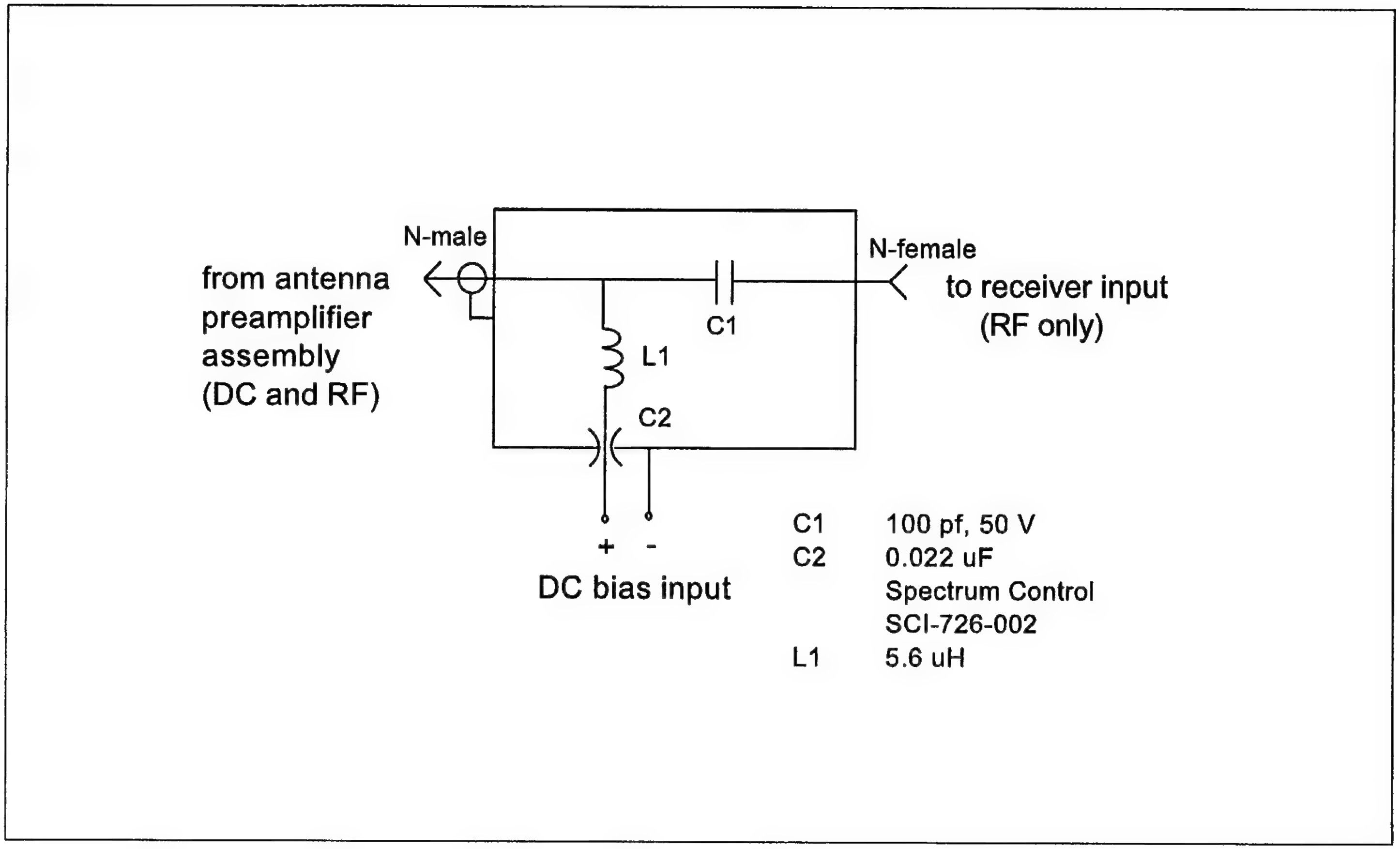

Figure A.5. SATSIN DC bias T circuit

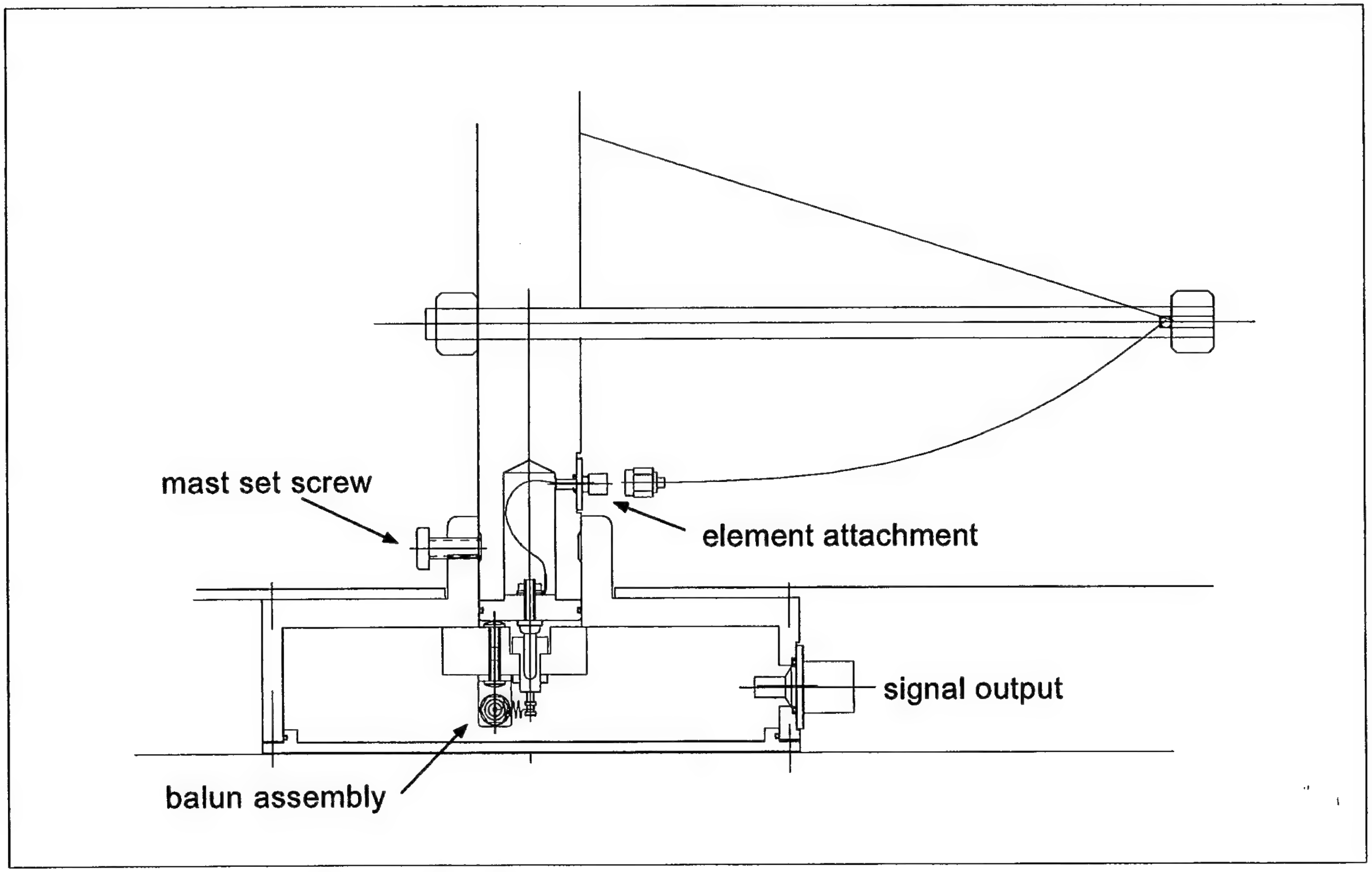

Figure A.6. Detail of preamplifier assembly and mast attachment

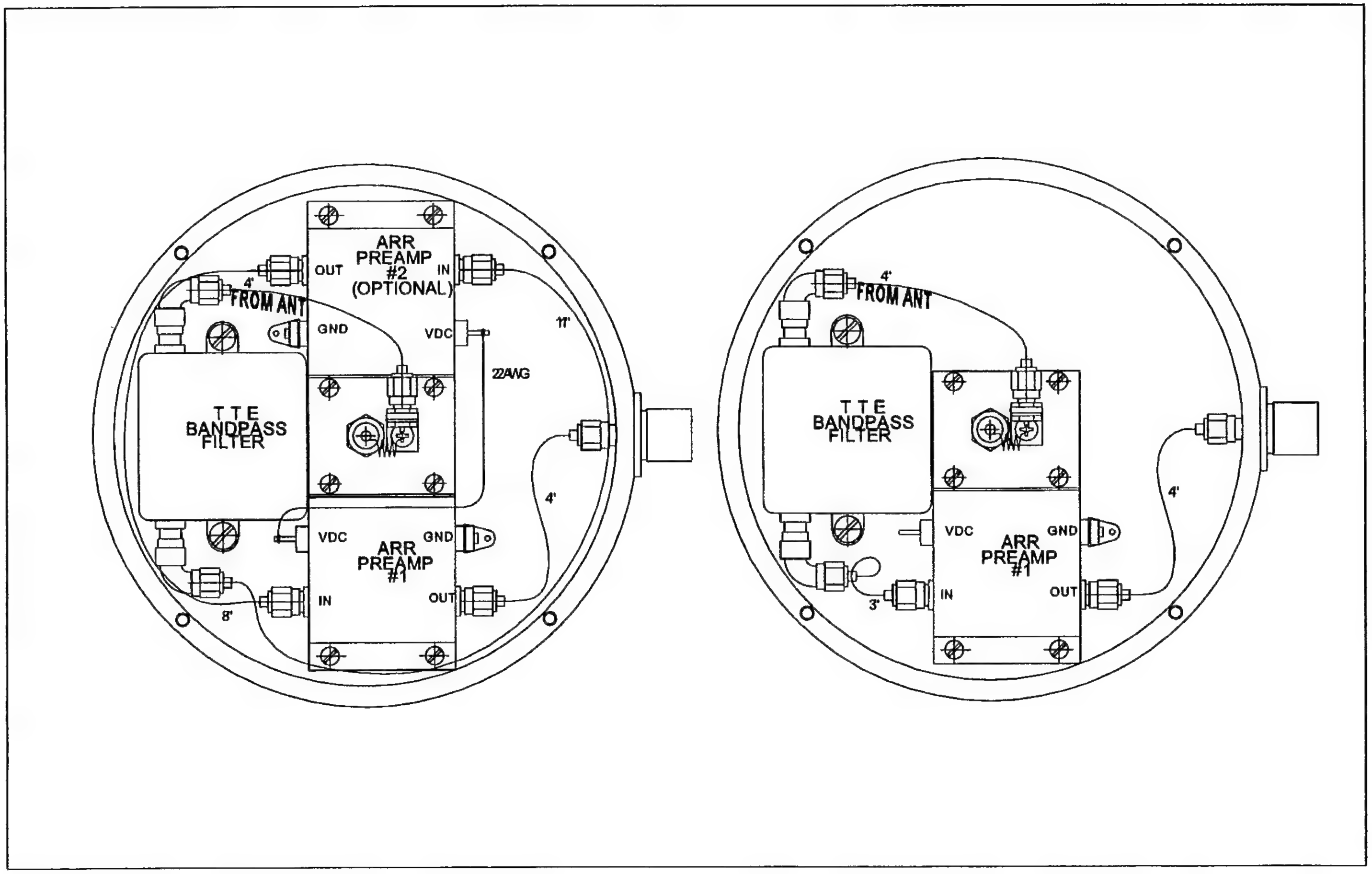

Figure A.7. Preamplifier assembly layouts for single and dual amplifier units

DAT Computer:

Description:	Passive backplane ISA bus computer
Manufacturer:	Diversified Technology, Inc. 112 E. State St. Ridgeland, MS 39158
Model:	CRM 710 chassis CAT1000 CPU
S/N:	16372 (chassis)
Specifications:	Intel 486 processor, 50 Mhz 16 Mbyte RAM DOS 6.21 OS
Documentation:	manufacturer's manuals for chassis, CPU and keyboard and manufacturer's manuals for interface cards, as delivered with the SATSIN system
Other:	interface card settings and information attached as Table A.2 normal boot-up commentary attached as Table A.3

Table A.2. DAT Computer interface card settings:

use	card	memory	interrupt	DMA	other
IDE	Ultrastor	320h-32Fh	6	--	
ethernet	Excelan 3C503	310h	5	--	note 1
ADC	Data Tran DT2838	260h	software	software	note 2
IEEE488	National AT-GPIB	2C0h	disabled	disabled	note 3
serial	--	3F8h-3FFh	4	--	
parallel	--	378h-37Fh	7	--	
video	--	--	--	--	

note 1: additional information for Excelan 3C503

EPROM disabled (J2 in)
memory address 310h (J3 in, J4 out)
SQE test enabled (J9 out)
CRS sense (J8 out)
enhanced mode (J10 2-3, J11 2-3, J12 1-2)
interrupt IRQ5 (J15 in)
converter power ON (J5 2-3)
AUI power off (J6 1-2)
SQE test enabled (J7 2-3)

software: Excelan LAN WorkPlace for DOS version 4.2
software: Excelan NFS Client for DOS version 3.0

note 2: additional information for DT2838 ADC

memory address 260H (set in CONFIG.SYS)
interrupt allocated in software driver source code
DMA channels allocated in software driver source code

software: Software Toolkit DT2831/DT3831 Series version 1.1

note 3: additional information for National AT-GPIB

memory address 2C0H (U25 A6, A7, A9 on)
interrupt disabled (all IRQs on W2, W3 out)
DMA disabled (all DRQ and DACK out)

software: NI 488.2 AT-GPIB for DOS version 2.1.1

Table A.3. Normal DAT computer boot sequence

```
Phoenix 80486 ROM BIOS PLUS Version 0.20.01
Copyright (C) 1985-1990 Phoenix Technologies Ltd.
All Rights Reserved

DIVERSIFIEDTECHNOLOGY CATIOOO Release 1.14
Starting MS-DOS...

MS-DOS 6.21 Startup Men
1. CMDLINE
2. ROUTOPS
Enter a choice: 1
Time remaining: 57

HIMEM.- DOS XMS Driver, Version 3.10 - 09/30/93
Extended Memory Specification (XMS) Version 3.0
Copyright 1988-1993 Microsoft Corp.
Installed A20 handler number 12,1. 64K High Memory Area is available.

National Instruments AT-GPIB NI-488.2 DOS Handler Version 2.1.1     Successfully Installed.
     Version Date- Aug 12 1992  Time= 16=36=04 Copyright 1992 National Instruments Corporation
GPIBO:
Base address is hex 2C0
DMA is DISABLED.  Using Programmed I/O.
Interrupts are disabled.

Data Translation (R) DT283x / DT383x Family Device Driver [SPO131] Version= V02.02
Copyright (C) Data Translation Inc. 1989 - 1992. All rights reserved.
Device at 0260h is DT2838

NFS Client for LAN WorkPlace Ethernet Driver V3.0c installed. (c) Copyright 1988, 1991, Beame &
Whiteside Software Ltd. 8192 buffer space used.
NetWare Link Support Layer  vl.21 (920130)
(C) Copyright 1990,  1992 Novell, Inc.   All Rights Reserved.

Int 5, Port 310, Mem CCOO0, Node Address 80014890849 L Max Frame 1514 bytes, Line Speed 10 Mbps
Board 1, Frame ETHERNET II, LSB Mode
Novell TCP/IP Transport'v4.12 (930928)
(C) Copyright 1992 Novell, Inc.  All Rights Reserved.

Network Name: IP NET                    Bind: EXOS
IP Address: 128.18.44.192               Board Number: 1
Subnet Mask: 255.255.0.0                Board Instance.- 1
Default Router: 128.18.10.1             Frame.- ETHERNET II
LWPRPC V3.0c NFS Client for LAN WorkPlace (Remote Procedure Call) (c) Copyright 1988, 1989, 1993
Beame & Whiteside Software Ltd. LWPNFS V3.0d NFS Client for LAN WorkPlace (Network File
System) (c) Copyright 1988, 1989, 1991 Beame & Whiteside Software Ltd.
```

DIS Computer:

Description:	UNIX workstation.
Manufacturer:	Sun Microsystems, Inc. 2550 Garcia Ave. Mountain View, CA 94043-1100
Model:	Sparc5 Model 70
S/N:	TBD
Specifications:	70 MHz MicroSPARC II processor 32 Mbytes RAM 1.05 Gbyte SCSI-2 disc internal TurboGX 8-bit Accelerated 2-D/3-D video 17 inch color monitor
Documentation:	manufacturer's manuals delivered with the system
Other:	normal boot-up commentary attached as Table A.4

Table A.4. Normal DIS computer boot sequence

```
Jun 19 14:20
SunOS Release 5.4 Version generic [UNIX(R) System V Release 4.0]
Copyright (c) 1983-1994, Sun Microsystems, Inc.
pac: enabled - SuperSPARC/SuperCache
cpu0: TI,TMS390Z55 (mid 8 impl 0x0 ver 0x3 clock 60 MHz)
mem = 32768K (0x2000000)
avail mem = 26677248
Ethernet address = 8:0:20:73:42:9a
root nexus = SUNW,SPARCstation-20
iommu0 at root: obio 0xe0000000
sbus0 at iommu0: obio 0xe0001000
espdma0 at sbus0: SBus slot f 0x400000
esp0 at espdma0: SBus slot f 0x800000 sparc ipl 4
sd3 at esp0: target 3 lun 0
sd3 is /iommu@f,e0000000/sbus@f,e0001000/espdma@f,400000/esp@f,800000/sd@3,0
        <SUN1.05 cyl 2036 alt 2 hd 14 sec 72>
sd6 at esp0: target 6 lun 0
sd6 is /iommu@f,e0000000/sbus@f,e0001000/espdma@f,400000/esp@f,800000/sd@6,0
root on
/iommu@f,e0000000/sbus@f,e0001000/espdma@f,400000/esp@f,800000/sd@3,0:a
fstype ufs
obio0 at root
zs0 at obio0: obio 0x100000 sparc ipl 12
zs0 is /obio/zs@0,100000
zs1 at obio0: obio 0x0 sparc ipl 12
zs1 is /obio/zs@0,0
cgsix0 at sbus0: SBus slot 2 0x0 SBus level 5 sparc ipl 9
cgsix0 is /iommu@f,e0000000/sbus@f,e0001000/cgsix@2,0
cgsix0: screen 1152x900, single buffered, 1M mappable, rev 11
cpu 0 initialization complete - online
ledma0 at sbus0: SBus slot f 0x400010
le0 at ledma0: SBus slot f 0xc00000 sparc ipl 6
le0 is /iommu@f,e0000000/sbus@f,e0001000/ledma@f,400010/le@f,c00000
dump on /dev/dsk/c0t3d0s1 size 33252K
syncing file systems... [13] [13] [8] done
```

Network Repeater:

Description:	Ethernet repeater.
Manufacturer:	Allied Telesys 575 E. Middlefield Road Mountain View, CA 94043
Model:	AT-MR122T Micro Repeater
S/N:	GONF4259H
Specifications:	dual port (UTP, BNC)
Documentation:	manufacturer's manual delivered with the system
Other:	--

Network Serial Router:

Description:	Serial routers (2 each) with built-in modem to connect thinwire ethernet local networks via telephone.
Manufacturer:	TBD (e.g. Rockwell)
Model:	TBD (e.g. Rockwell NH-P NetHopper)
S/N:	TBD
Specifications:	thin-wire ethernet input V.32 and V.42 BIS for modem speed to 14.4 KBaud
Documentation:	--
Other:	--

GPS Receiver:

Description:	GPS receiver with software interface.
Manufacturer:	Trimble Navigation Limited 585 North Mary Ave. Sunnyvale, CA 94086 Mountain View, CA
Model:	Acctime Smart Antenna, P/N 23201-61
S/N:	0080112885
Specifications:	six satellite coverage RS232 output to computer
Documentation:	manufacturer's manuals delivered with the system
Other:	connection diagram attached as Figure A.8

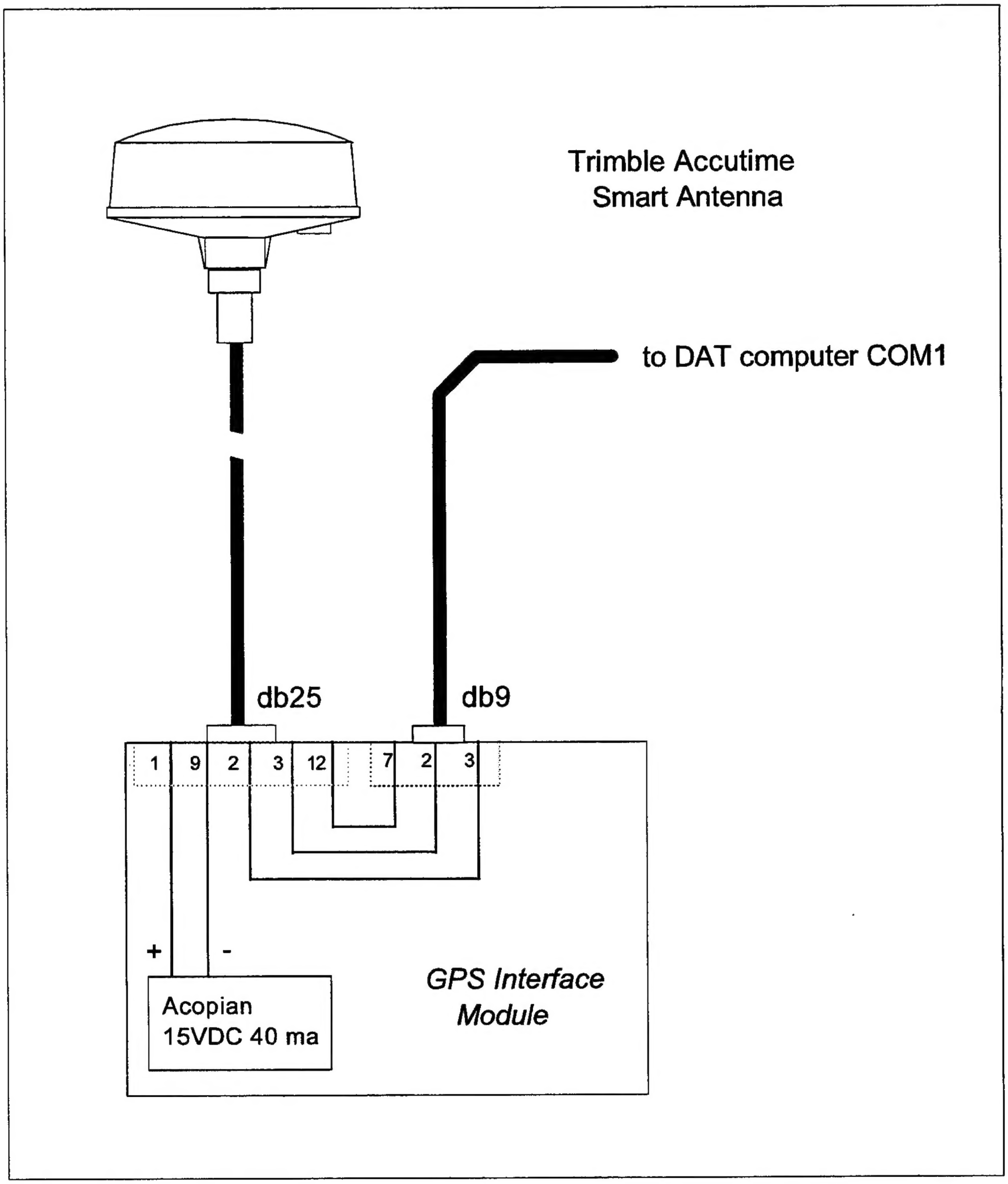

Figure A.8. GPS receiver connections